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ABSTRACT

Listed in this science syllabus are concepts and understandings in eight major areas: (1) forces, motion, and work; (2) introduction to energy; (3) mechanical energy and machines; (4) sound energy; (5) electromagnetic energy and light energy; (6) heat energy; (7) electric and magnetic energy; and (8) nuclear energy. The booklet also includes questions for students to answer and, when applicable, a code to an activity presented in an appendix. Program objectives and performance criteria are provided for each of the areas, as is a list of 23 science processes keyed to the activities. Three appendices are included. Appendix A contains the activities (cross-referenced in the concept/understanding outline). Each activity includes a purpose, materials list, procedures, and discussion of results. Although some teacher demonstrations are presented, most involve simple equipment and procedures which students can use and complete within half an hour. All activities are designed to assist students in attaining the program objectives. Appendix B is a resource table of units and formulas. Appendix C contains reference stories on energy and motion, noise level listings for common sounds, and a discussion of how color affects human moods and health. (DH)

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ENERGY & MOTION

Science Syllabus for Middle and Junior High Schools

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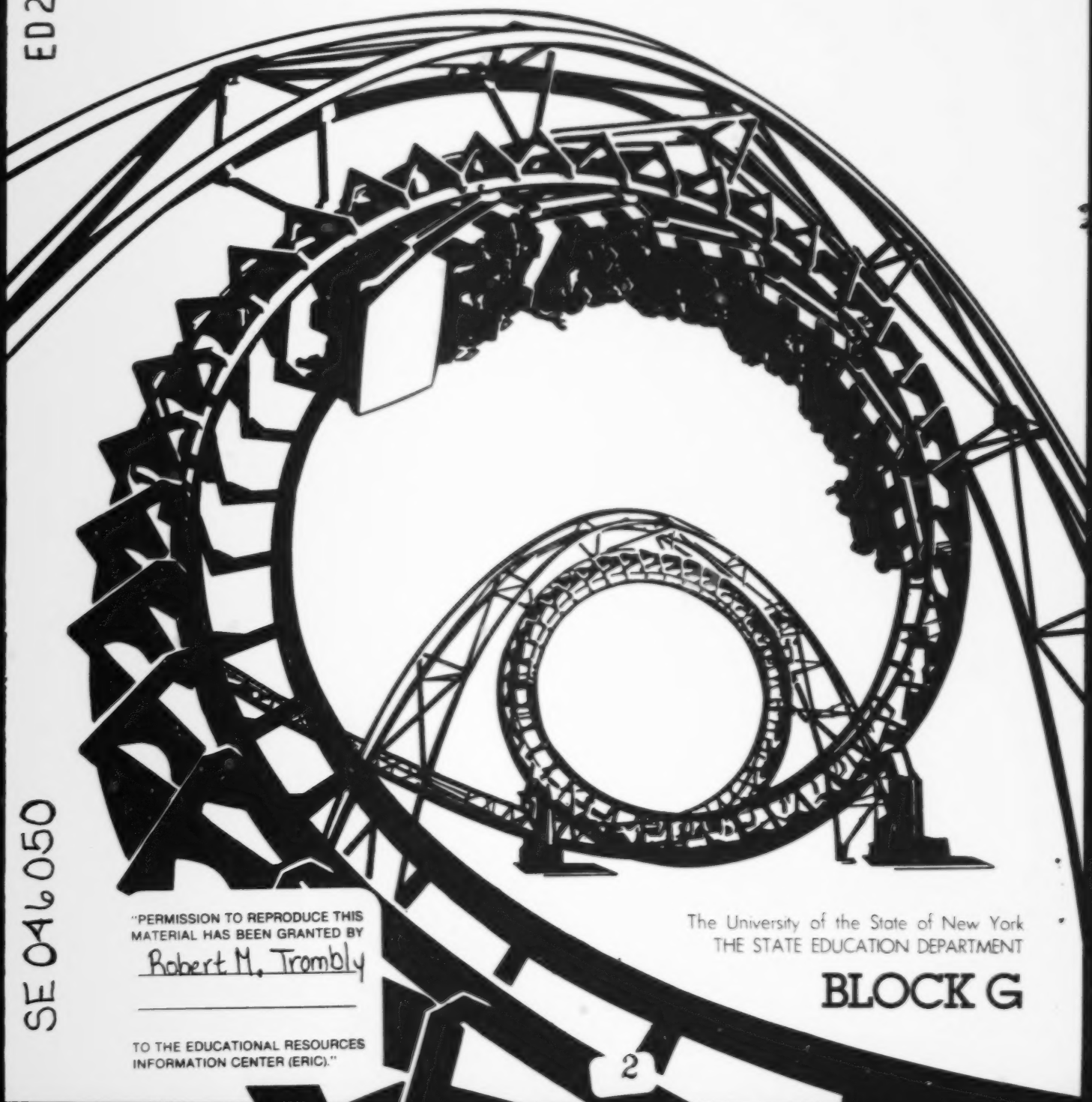

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FOREWORD

This publication is the eighth product of the project which significantly revises and updates the Science Syllabus for Middle and Junior High Schools. The project will result in a group of instructional blocks encompassing the content and skills in the biological, physical, and earth sciences appropriate for those grade levels.

The understandings, questions, and learning activities in the publication have been enhanced by the inclusion and referencing of program objectives, performance criteria, and process skills which serve to focus student achievement.

These objectives and performance criteria are provided in a general outline which conforms to the content subdivisions in the publication. Process skills are keyed to the learning activities in **Appendix A** and the learning activities are keyed to the understandings and the questions.

A resource, *Table of Units and Formulas for Physical Science*, is provided in **Appendix B** while **Appendix C** contains readings which are referred to in the activities.

The materials in this publication were prepared by **Sam Walters** and **Pete Snyder**, South Glens Falls Junior High School; **Jane E.Cappiello**, Bethlehem Central School; and **Joanne Gallagher**, Brunswick Central School.

A number of teachers reviewed various drafts of the publication and made important recommendations for revision. These included: **Charles Kish,** Saratoga Springs City School District; **Douglas Larison,** Lansing Central School; **Robert Lehrman** and **Salvatore Vaccaro,** Roslyn Central School; and **Robert Neff**, Suffern Central School.

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PROGRAM OBJECTIVES AND PERFORMANCE CRITERIA

The program objectives and performance criteria below are provided as an aid in ordering the direction and synthesizing the outcomes of the instruction related to this block. The objectives and outcomes (performance) described below for this program permit latitude in the selection of content. It is implied that student knowledge, understanding, and skills accrued as a result of content selection and instruction will be demonstrable in the manner and to the minimum extent described.

I. FORCES, MOTION, AND WORK

Program Objectives	Performance Criteria
The student will be able to identify and analyze different kinds of forces.	Given a specific example of forces acting on an object, the student will determine whether the forces are balanced or unbalanced. Given appropriate examples of the forces of gravity and friction, the student will correctly identify each example.
The student will be able to differentiate two types of motion.	Given an object moving at a constant speed, the student will measure its speed. Given an object whose motion is changing, the student will identify its motion as accelerated motion.
The student will be able to describe the laws governing the motion of objects, and illustrate how these laws apply to everyday experiences.	Given the appropriate equipment, the student will demonstrate each law of motion and describe a practical application of each.
The student will be able to describe the nature of work.	Given a specific example of work being done, the student will determine the amount of work done.

II. INTRODUCTION TO ENERGY

The student will be able to analyze an event or a system, and describe the forms of energy involved.	Given a specific event or system, the student will name all the forms of energy involved and indicate where, during the event or in the system, energy has changed form.

1

The student will be able to describe the law of conservation of energy.

The student will give examples of conversions between kinetic and potential energy, and indicate where any "lost" energy may have gone.

III. MECHANICAL ENERGY AND MACHINES

The student will be able to analyze some simple machines and describe the advantages of using machines.

Given a simple machine, the student will determine the input work, the output work, and the efficiency of the machine.

Given a simple machine, the student will identify the machine and determine whether it multiplies force, multiplies distance or speed, or changes the direction of the force.

IV. SOUND ENERGY

The student will be able to describe the nature and behavior of sound and give some examples of how sound affects our everyday lives.

Given the appropriate equipment, the student will demonstrate the production and transmission of sound.

Given a property of sound (such as pitch, loudness, reflection and absorption, or resonance), the student will describe and/or demonstrate how the property affects human behavior, health, or safety.

V. ELECTROMAGNETIC ENERGY AND LIGHT ENERGY

The student will be able to describe the nature and behavior of light energy.

Given the appropriate equipment, the student will describe and/or demonstrate the properties of light including color, intensity, reflection, refraction, and its travel in a straight line.

The student will be able to give some examples of how electromagnetic energy affects our everyday lives.

The student will give three examples of beneficial uses and three examples of harmful effects of electromagnetic energy.

VI. HEAT ENERGY

The student will be able to describe the nature and behavior of heat energy.

The student will use the particle model for heat to explain the expansion and contraction of matter, the phases of matter, change of phase, temperature, and heat transfer.

	Given the appropriate equipment, the student will demonstrate how heat energy is transferred by conduction, convection, and radiation, and describe a practical application of each method.

VII. ELECTRIC AND MAGNETIC ENERGY

The student will be able to describe the nature and behavior of magnetism.	Given the appropriate equipment, the student will demonstrate the properties of a magnet and the existence and interaction of magnetic fields.
The student will be able to describe the nature and behavior of static and current electricity.	Given the appropriate equipment, the student will produce charged objects and demonstrate their properties.
	Given the appropriate equipment, the student will produce current electricity and demonstrate its properties.
The student will be able to analyze an electric circuit.	Given a simple electric circuit, the student will identify it as a series or parallel circuit.
	Given an electric circuit and appropriate meters, the student will determine the voltage and current in the circuit, and identify the resistance.
The student will be able to explain the relationship between magnetism and electricity and identify applications of this relationship.	Given the appropriate equipment, the student will demonstrate the interaction of magnetism and electricity by producing an electric current and an electromagnet.
The student will be able to describe two methods for making electricity safer.	Given a fuse or a circuit breaker, the student will identify its purpose and describe its correct use.

VIII. NUCLEAR ENERGY

The student will be able to describe the nature of nuclear energy and the types of nuclear change that may occur.	The student will identify the types of radiation given off by a radioactive material.
	Given examples of radioactive decay, fission, and fusion,the student will correctly identify them.
The student will be able to describe some beneficial and harmful effects of, and some safety precautions that must be taken with, nuclear energy.	The student will identify two situations in which nuclear energy is beneficial and two situations in which it is potentially harmful.
	The student will identify two situations in which safety precautions must be taken with nuclear energy.

PROCESSES

One of the major objectives in all science courses is the development of competence in processes used in science. The learning activities beginning on p. 33 in this publication will assist students in attaining this objective. Each activity is keyed to one or more of the processes listed below. For example, activity **(G-1)** involves processes **(1)** and **(14)**

(1) Observing objects and phenomena
(2) Describing observations
(3) Selecting suitable measuring instruments
(4) Developing skills in using laboratory equipment
(5) Measuring objects and phenomena
(6) Performing laboratory techniques
(7) Estimating measurements within limits of accuracy
(8) Recognizing a problem
(9) Formulating a working hypothesis
(10) Designing appropriate tests of a hypothesis
(11) Designing suitable procedures for experimental tests
(12) Processing experimental data
(13) Organizing data to show a functional relationship
(14) Interpreting observations and data
(15) Interpolating and extrapolating
(16) Evaluating a hypothesis in the light of data obtained
(17) Formulating generalizations based on relationships
(18) Recognizing the need for a theoretical model
(19) Formulating a theoretical model to accommodate knowledge
(20) Designing relationships satisfied by a model
(21) Deducing a hypothesis from a theoretical model
(22) Interpreting and evaluating tests of a model
(23) Producing a revised, refined, or extended model

CONCEPTS AND UNDERSTANDINGS—QUESTIONS AND ACTIVITIES

I. FORCES, MOTION, AND WORK

Concepts and Understandings	Questions and Activities

A. FORCE

1. Nature of force

A force cannot be seen. Its presence can be inferred from its effect on an object.

a. Balanced forces

(1) When an object is in equilibrium, all of the forces acting upon it at the same time are balanced.

(2) When the forces on an object balance one another, an object at rest will remain at rest and an object in motion will continue to move at a constant speed and in the same direction.

(3) When the forces on an object balance one another, the object may change shape.

What is the difference between balanced and unbalanced forces? **(G-1)**

b. Unbalanced forces

When the forces on an object do not balance, a change in the shape or motion of the object occurs. A change in motion can be a change in speed, a change in the direction of motion, or both.

2. Some kinds of forces

a. Gravity

(1) Relationship to weight

All objects in the universe attract one another. Weight is a measure of the force of attraction that a larger object exerts on a smaller one.

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(2) Relationship to mass

Mass measures the amount of matter in an object. The force of attraction between two objects increases as the mass of either object increases, and decreases as the distance between the objects increases.

b. Friction

Friction opposes the motion of objects in contact. Friction produces heat.

3. Units of force and mass

a. Force

In the metric system, force is usually measured in newtons.

b. Mass

In the metric system, mass is measured in grams.

What is the relationship between mass and weight? **(G-2)**

How are mass and weight different?

In everyday terms, we think of mass and weight as being the same on Earth. For example, cereal boxes are labeled "Net weight: 16 oz. (45 g)." Is this really accurate?

Why is friction a force? **(G-3)**

How are gravity and friction alike and how do they differ?

B. MOTION

1. Nature of motion

When an object is in motion, its position as compared to a reference point changes.

a. Speed

The motion of an object can be stated in terms of its speed. Speed is the distance traveled by an object in a unit of time.

How can speed be calculated? **(G-4)**

b. Acceleration

The motion of an object can be stated in terms of its acceleration. An object accelerates whenever it starts, stops, changes speed, or changes direction. Any of these changes can only be caused by unbalanced forces acting on the object.

What is positive acceleration?

What is negative acceleration (deceleration)?

2. The laws of motion

a. Inertia

An object at rest tends to stay at rest. An object that is moving tends to keep moving at the same speed and in the same direction.

What is inertia? **(G-5)**

Which has greater inertia, a large mass or a small mass? **(G-6)**

b. Inertia and acceleration

(1) Some objects accelerate more easily than others. These objects have less inertia.

(2) An unbalanced force acting on an object will cause the object to accelerate.

(3) The acceleration is greater when the force is greater.

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(4) The acceleration is greater when the mass of the object is less.

c. Action and reaction

Every action force is accompanied by a reaction force that is equal to the action force and opposite in direction. The action and reaction forces act on different objects.

How can the action and reaction that accompany a force be demonstrated? **(G-7)**

How is a rocketship able to accelerate in space, where there is no air against which to push?

d. Applications of the laws of motion

(1) The laws of motion apply to all objects in all situations.

(2) Safety belts and child restraint seats protect automobile passengers from the effects of the laws of motion.

How do the laws of motion affect passengers in an automobile as it speeds up or slows down rapidly? **(G-8)**

C. WORK

1. Nature of work

Work is done whenever a force causes an object to move through a distance. The amount of work done on an object is determined by multiplying the force on an object by the distance the object moves.

What are the differences in the use of the term "work" in the scientific sense and in the everyday sense?

How can we determine the work done in lifting an object? **(G-9)**

2. Unit of work

In the metric system, one joule (newton-meter) of work is done when a force of one newton acts through a distance of one meter.

II. INTRODUCTION TO ENERGY

A. ENERGY AND WORK

Any object that can do work has energy. When work has been done on an object, its energy increases.

What are some situations in everyday life in which energy is present?

B. THE KINDS OF ENERGY

1. Potential energy

Some objects have stored energy because of their position or their chemical or atomic composition.

What is the relationship between the potential energy of an object and the amount of work it can do? **(G-10)**

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2. Kinetic energy

A moving object has energy because of its motion.

What is the relationship between the mass and speed of an object and its kinetic energy? **(G-11)**

How can potential energy be converted to kinetic energy and vice versa? **(G-12)**

C. SOME FORMS OF ENERGY

Objects possess different forms of kinetic and potential energy. The forms of energy include mechanical, sound, electromagnetic, heat, electrical, magnetic, chemical, and nuclear energy.

What are some of the forms of energy we use every day? **(G-13)**

D. CONSERVATION OF ENERGY

Energy can be transformed from one kind and form to another. When energy is transformed, the total amount of energy always stays the same. Energy never disappears; it changes to, and appears in, another form.

Use the law of conservation of energy to explain how the amount of electrical energy supplied to accelerate a toy train is greater than the amount of kinetic energy the train achieves.

What are some situations in which one form of energy is converted into another?

When energy is transformed, some is wasted (lost) because of friction. How can we say, then, that energy is conserved?

III. MECHANICAL ENERGY AND MACHINES

A. NATURE OF MACHINES

Mechanical energy is transferred from one point in space to another through machines. Mechanical energy may be potential or kinetic.

Why is the wheel considered to be one of the most important early machines invented? **(G-14)**

1. Law of machines

Under ideal conditions, the amount of work that is put into a machine is equal to the amount of work that the machine does.

Do machines decrease the amount of work done?

Do ideal conditions ever really exist? With this in mind, can a machine's work output ever be more than the work put into it?

2. Effort and resistance

When a machine is used, an effort force is applied to the machine to overcome a resistance force.

What is the difference between the effort force and the resistance force?

3. Input work

The work put into any machine can be determined by

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multiplying the effort force by the distance through which this force acts.

4. Output work

The work done by any machine can be determined by multiplying the resistance force by the distance through which this force acts.

5. Efficiency

a. Input work compared to output work

No machine is 100 percent efficient. The work put into the machine is always greater than the work done by the machine. Some of the work put into the machine must be used to overcome friction, and warms up the machine.

Why is the work done by a machine always less than the amount of work that is put into the machine? How can this be explained if energy is conserved?

b. Determining efficiency

The efficiency of a machine can be determined by dividing the work output by the work input.

c. Increasing efficiency

A machine can be made more efficient by reducing friction. Some common ways of reducing friction include lubricating or waxing surfaces, sanding surfaces to make them smoother, or using ball bearings.

What are some ways to increase the efficiency of a machine?

B. USE OF MACHINES

Machines make work seem "easier" or "faster."

What are the functions of a machine? **(G-15)**

1. Machines can change the direction of the force

The direction in which a force is applied can be changed by using a machine.

2. Machines multiply force

Many machines are used to multiply force. A large resistance force can be overcome with a comparatively small effort force, but the effort force must be exerted through a greater distance.

What are some practical situations in which machines are used to change the direction of the force and/or to multiply the force? **(G-16)**

a. Mechanical advantage

The mechanical advantage (MA) of a machine tells how many times the machine multiplies the effort force.

b. Ideal mechanical advantage

(1) The ideal mechanical advantage (IMA) of any machine is the number of times that it will multiply the effort under conditions in which there is no force of friction to be overcome and in which the weight of the machine itself is ignored.

(2) The ideal mechanical advantage can be determined by dividing the distance the effort force moves by the distance the resistance force moves when the machine is operated.

What are some practical limitations which prevent the design of machines with extremely high ideal mechanical advantages?

c. Actual mechanical advantage

(1) In any machine, some of the effort force must be used to overcome the force of friction, and in some cases, the weight of the machine itself. The actual mechanical advantage of a machine is always less than the ideal mechanical advantage.

Why is the actual mechanical advantage always less than the ideal mechanical advantage?

(2) The actual mechanical advantage (AMA) of a machine can be determined by dividing the resistance force by the effort force.

3. Machines multiply distance

Some machines multiply distance. A large effort force moves a smaller resistance force a greater distance.

What machines are used principally for multiplying distance?

4. Machines multiply speed

Some machines multiply speed. A large, slow-moving effort force moves a smaller resistance force at a greater speed.

How do the gears on a drill or on a 10-speed bicycle multiply speed?

C. SIMPLE MACHINES

Simple machines include the lever, wheel and axle, pulley, inclined plane, wedge, and screw.

1. The lever

The lever consists of a rigid bar which is rotated about a fulcrum.[7] A lever has an effort arm and a resistance arm.

What is the relationship between the length of a lever's effort arm and the effort force? **(G-17)**

a. Classification of levers

Levers may be classified according to the relative positions of the fulcrum, effort force, and resistance force.[8]

How many classes of lever are there?

What are some common levers? Where are the fulcrum, effort force, and resistance force located on each? **(G-18)** Which of the four uses of machines (changing direction, multiplying force, multiplying distance, or multiplying speed) does each lever accomplish?

b. Mechanical advantage

The ideal mechanical advantage of a lever can be determined by dividing the length of the effort arm by the length of the resistance arm.[9]

c. Efficiency

Most levers have very little friction. As a result, they have a high efficiency.

d. Variations of the lever

The pulley and the wheel and axle are modifications of the lever. Gears are also modified levers.

How are wheel and axles, pulleys, and gears like levers?

2. The inclined plane

An inclined plane is used to raise heavy objects to a higher position.[10] An object is moved a longer distance along the slant of the plane to raise the object the same distance in height as without the plane.

What are some examples of inclined planes?

What is the relationship between the height of an inclined plane and the effort force that must be applied to raise an object.? **(G-19)**

a. Mechanical advantage

(1) Ideal mechanical advantage

The ideal mechanical advantage of an inclined plane can be determined by dividing the length of the plane by its height.

How can we calculate the ideal and actual mechanical advantage for an inclined plane? **(G-20)**

(2) Actual mechanical advantage

The actual mechanical advantage of an inclined plane can be determined by dividing the resistance force (the weight of the object) by the effort force.

b. Input work

The work put into the inclined plane can be determined by multiplying the effort force by the distance the resistance force is moved along the plane.

c. Output work

The work done by an inclined plane can be determined by multiplying the resistance force by the height of the plane.

d. Efficiency

The efficiency of an inclined plane depends on the amount of friction between the surface of the plane and the surface of the object moved.

How can we determine the efficiency of an inclined plane? **(G-20)**

e. Variations of the inclined plane

(1) A screw is an inclined plane that is twisted into a spiral shape.

(2) A wedge consists of two inclined planes placed back to back.

Why are screws and wedges considered to be variations of the inclined plane?

D. COMPLEX MACHINES

Complex machines are made up of two or more simple machines.[11]

What is the relationship between simple and complex machines? **(G-21)**

E. MORE ON MECHANICAL ENERGY AND MACHINES

Complex, engine-driven machines are an important element in modern life. Before the industrial revolution, most work was done by human or animal labor. Today, engine-driven machines do much of that work for us.

How would your life be different without machines?

What are the sources of the energy that exerts the effort force in complex machines?

IV. SOUND ENERGY

A. NATURE OF SOUND ENERGY

Sound is produced by vibrating matter. Sound energy is a form of kinetic energy that travels in waves.

How can we show that sound is produced by vibrating matter? **(G-22)**

B. PROPERTIES OF SOUND

1. Type of wave

Sound waves are longitudinal waves. As longitudinal waves move through a medium, the molecules of the medium are alternately closer together and farther apart than when in the rest position. The molecules vibrate back and forth in the same direction as the wave moves.

What are the differences between longitudinal and transverse waves? **(G-23)**

2. Frequency and pitch

a. Frequency

The faster a source of sound vibrates, the greater the frequency of the waves it produces.[12] Frequency is measured in vibrations/second.

b. Pitch

Sound waves of different frequencies have different pitches. The greater the frequency of a sound wave, the higher the pitch of the sound.

As the frequency of a sound wave changes, what happens to the pitch of the sound? **(G-24)**

c. Doppler effect

The Doppler effect is caused by a perceived change in the pitch of sound waves when an observer or the source of the sound waves is moving.[13]

What is an example of the Doppler effect?

3. Wavelength

Sound waves of different frequencies have different wavelengths. The greater the frequency of a sound wave, the shorter its wavelength.

What is the relationship between wavelength and frequency?

4. Loudness

a. Amplitude of the sound wave

The loudness of a sound depends upon the amplitude of its sound wave. The greater the amplitude of a sound wave, the louder its sound.

How can we increase loudness? **(G-25)**

b. Measurement

The loudness of a sound can be indicated by its decibel level (dB).

5. Absorption and reflection

Sound waves may be absorbed or reflected by a material. When sound waves are reflected, an echo results.[14]

In what situations might one want to have sound waves absorbed?

How can we use reflected sound waves to measure the speed of sound? **(G-26)**

6. Resonance

A sound source can cause another object to vibrate if the frequency of the source and object properly match.[15,16]

What are some examples of resonance? **(G-27)**

C. TRANSMISSION OF SOUND WAVES

Sound waves require matter through which to travel.

How can we demonstrate that sound requires matter through which to travel? **(G-28)**

1. Path of sound waves

Sound waves do not travel in straight lines.

2. Speed of sound

a. The speed of sound depends on the type of matter and the temperature of the matter the sound waves are moving through.

Does sound travel fastest in a solid, a liquid, or a gas?

How does the speed of sound vary with temperature?

b. The speed of sound is quite slow compared to the speed of light.

D. MORE ON SOUND ENERGY

1. Music

Music consists of many sound waves following a pattern. Music affects us physically, emotionally, and socially.[18]

How does music affect living things? **(G-29)**

2. Noise

Noise consists of unwanted or unpleasant sounds.

a. Loss of hearing

Loud noise can damage hearing temporarily or permanently.

b. Noise pollution

Noise has become a problem in modern society. Noise can cause emotional, physical, and social problems.

How can noise affect your health?**(G-30)**

How do local industries regulate noise?**(G-31)**

3. Ultrasound

Ultrasonic waves are used in medical diagnosis and therapy.

What are some specific medical uses of ultrasonic waves?

V. ELECTROMAGNETIC ENERGY AND LIGHT ENERGY

A. ELECTROMAGNETIC ENERGY

Electromagnetic energy is transferred by waves. These waves are able to move through empty space at the speed of light.[1-2]

1. Sources

The Sun is our major source of electromagnetic energy. Electromagnetic waves can also be produced by electricity or magnetism.

How does an incandescent lamp produce electromagnetic radiation?

2. Classification

There are many different kinds of electromagnetic waves. Each kind has a characteristic range of wavelengths and frequencies. When electromagnetic waves are arranged in order of their wavelength and frequency, the result is the electromagnetic spectrum.[2]

What are the parts of the electromagnetic spectrum? **(G-32)**

B. LIGHT ENERGY

Light waves are only a small portion of the electromagnetic spectrum. Visible light waves can be detected by the human eye.

1. Sources of light

The Sun is the major source of light. Other natural

sources include lightning and fire. One artificial source is the light bulb.

2. Properties of light

a. Type of wave

Light waves behave as if they were transverse waves.

How are transverse waves different from longitudinal waves? **(G-23)**

b. Color

(1) The visible light spectrum consists of several colors.

How can we demonstrate that white light is composed of many colors? **(G-33)**

(2) The frequency (or wavelength) of a wave in the visible light spectrum determines its color.[22]

c. Path of light waves

Light waves travel away from a source in straight lines called rays.

How can we demonstrate that light travels in straight lines? **(G-34)**

d. Intensity and illumination

The amount of light falling on a surface (illumination) increases as the intensity of the source increases and decreases as the distance from the source increases.

How does illumination change when distance from the source increases? **(G-35)**

e. Reflection

When light strikes a surface some light waves will be reflected, some will be absorbed, and some may be transmitted.

(1) Law of reflection

The angle at which a light ray strikes a reflecting surface is equal to the angle that the reflected ray makes with the same surface.

How is light reflected? **(G-36)**

(2) Plane mirrors

Plane mirrors reflect light rays in a regular pattern. The images formed by plane mirrors are right side up, and appear to be as far behind the mirror as the object is in front of the mirror.

What kind of images do plane mirrors form? **(G-37)**

f. Refraction

Light rays bend as they pass from one material into another.

What happens to light as it passes from one substance to another? **(G-38)**

How does the refraction of light affect us as we look into water or through clear glass or plastic?

(1) Law of refraction

When a light ray enters a material and its speed decreases, the ray is bent towards the normal. When a light ray enters a material and its speed increases, the ray is bent away from the normal.

(2) Lenses

Lenses refract light rays, forming images that may be larger, the same size as, or smaller than the object.[23]

What instruments use lenses?

What effect do lenses have on light rays?**(G-39)**

What kind of image does a lens form?**(G-40)**

C. MORE ON ELECTROMAGNETIC ENERGY

1. Beneficial Uses

Electromagnetic waves have many uses in modern society.

What are some of the beneficial uses of electromagnetic waves?

a. Radio waves are used in communication, especially radio and television broadcasting.

b. Microwaves are used in communication and in cooking food.

How do microwaves cook food?

What are some other uses of microwaves?

c. X-rays are used in diagnosing diseases.

d. Gamma rays are used to treat cancer.

e. Light waves in the form of lasers are used in medicine, communication, and research. Through the photoelectric effect, light waves can be directly converted to electricity. Light waves, through the use of appropriate colors, can affect our moods and behavior.

How does a laser work?

How is laser light different from other forms of light?

How are lasers used in communication?

How are lasers used with optical fibers to improve communication?

What are some other specific uses of lasers?

How do different colors affect our emotions and behavior? **(G-41)**

2. Harmful effects

Overexposure to electromagnetic waves may cause harmful effects in humans.

Recommended levels of exposure have been set for electromagnetic radiation. Is there any disagreement about these levels? Explain.

a. X-rays, gamma rays, and cosmic rays can cause illness or death.

b. Ultraviolet waves can cause skin cancer and burning of skin tissue.

c. Infrared waves can burn skin tissues.

d. High intensity light waves can cause permanent eye damage.

What is the best way to view a solar eclipse?

e. Microwaves may produce harmful effects.

3. Light energy and perceptions

a. Perception of color

(1) The color of an object comes from the wavelengths of the light reflected from the object's surface as they interact with the human eye.

(2) The color of the light reflected from a surface depends on the wavelengths of the light shining on the surface, the nature of the surface, and the ability of the human eye to perceive these wavelengths.[24]

Why do objects appear the color they do? **(G-42)**

b. Creation of optical illusions

(1) The properties of reflection, refraction, and absorption of light can be used to make objects appear different than they really are.

(2) Objects can also be made to look different by changing the wavelengths or intensity of the light source or by changing the color or composition of the surroundings.

Can you always trust your eyes? **(G-43, 44, 45)**

VI. HEAT ENERGY

A. THE PARTICLE MODEL FOR MATTER

Heat energy can be understood in terms of the kinetic energy possessed by the particles of matter.

Describe two models that explain the nature of heat energy. Which model do we currently use? **(G-46)**

What makes the particle model for matter a model?

1. Matter and particles

All matter is made up of particles in constant motion.

2. Particles and kinetic energy

When an object or material gains heat energy, its particles have more kinetic energy. When an object or material loses heat energy, its particles have less kinetic energy.[25]

3. Expansion and contraction of material

When an object or material gains heat energy, its particles gain potential energy and kinetic energy, and they usually move farther apart. The material expands. When an object or material loses heat energy, its particles lose potential energy and kinetic energy and usually move closer together. The material contracts.

Why do the particles move farther apart or closer together?

What usually happens to matter when it is heated? **(G-47, 48, 49)**

4. Change of phase

a. The phases of matter

Matter can exist in these phases: solid, liquid, and gas.

How can we describe the differences between these phases of matter? **(G-50)**

b. Particle rearrangement

(1) As the particles of a material gain kinetic energy and potential energy, a point may be reached where the particles become rearranged. When this happens, the material changes phase. A change of phase in this direction requires energy.

What happens to the temperature of a material as it changes phase? **(G-51)**

(2) When the particles reach a similar point as they lose kinetic energy and potential energy, the material changes phase in the opposite direction. A change of phase in this direction releases energy.

What substance expands when it freezes?

c. Direction of phase change

The direction of phase change with continued heat gain is from a solid to a liquid to a gas. In general, a material in the solid phase has less energy than in the liquid phase, which, in turn, has less energy than in the gas phase.

B. TEMPERATURE

1. Average kinetic energy of particles

An object at a high temperature is said to be hot. An object at a low temperature is said to be cold. Temperature measures the average kinetic energy of the particles in an object.

How is temperature measured? **(G-52, 53)**

2. Temperature change

When the kinetic energy of the particles in an object increases, its temperature increases. When the kinetic energy of the particles in an object decreases, its temperature decreases.

3. Measurement of temperature

A thermometer measures temperature. The metric unit of temperature is the degree Celsius (°C). The English unit of temperature is the degree Fahrenheit (°F).

How does a thermometer measure temperature? What scientific principle is involved?

How can a thermometer scale be made? **(G-54)**

C. HEAT

1. Heat transfer

Heat is transferred between objects as a result of the

How does heat differ from temperature?

difference in temperature between the objects. The amount of heat transferred between two objects increases as the temperature or mass of either object increases.

2. Calculating heat transfer for water

The amount of heat lost or gained by water can be calculated by multiplying the mass of the water (grams) by its change in temperature (°C).

How can we determine the amount of heat gained by water? **(G-55)**

3. Unit of heat

The metric unit of heat is the calorie (cal).

How is the calorie defined?

D. FLOW OF HEAT ENERGY

1. Direction of flow

Heat energy flows from warmer objects or regions (those at higher temperatures) to cooler objects or regions (those at lower temperatures). The warmer object becomes cooler and the cooler object becomes warmer until both objects are at the same temperature.

2. Methods of flow

Heat energy may be transferred by conduction, convection, and radiation.

a. Conduction

(1) Conduction occurs when heat energy is transferred from particle to particle in a material or across materials.

How does the particle model for matter explain conduction?

How can we demonstrate conduction? **(G-56)**

(2) Solids are usually the best conductors of heat energy. A material which conducts heat energy poorly is known as an insulator.

Why are solids usually the best conductors of heat?

What kinds of solids are the best conductors?

b. Convection

Convection occurs in unevenly heated liquids and gases. As the particles nearest the heat source gain energy and move farther apart, this portion of the fluid becomes less dense and rises. The cooler, more dense portion sinks and a convection current is set up.

How can we demonstrate convection? **(G-57)**

c. Radiation

(1) Radiation transfers heat energy through space by infrared waves. Infrared waves are electromagnetic waves and form a portion of the electromagnetic spectrum.

How can we demonstrate radiation of heat energy? **(G-58)**

What are infrared waves?

(2) One example of radiation is the heat energy that the Sun transmits to Earth. Radiation is the only method by which heat energy can be transferred through a vacuum.

What are some other examples of radiation?

Why can't heat be transferred through space by conduction or convection?

E. MORE ON HEAT ENERGY

1. Infrared photography

Certain photographic films are sensitive to infrared waves and allow us to "see" heat.

What are some of the ways infrared photography is used for our benefit?

2. Cryogenics

The physical and chemical properties of materials at very low temperatures are an important area of study.

What are some applications of cryogenics?

3. Thermal pollution

As machines convert energy, waste heat is produced. When large amounts of waste heat enter the atmosphere or bodies of water, the environment can be harmed.

What are some examples of thermal pollution?

How does each example harm the environment?

What is being done to control thermal pollution?

VII. ELECTRIC AND MAGNETIC ENERGY

A. MAGNETISM

Certain kinds of matter have magnetic energy.

Can all substances be attracted to magnets? **(G-59)**

1. Sources of magnets

a. Natural

Magnetite (lodestone) is a magnetic mineral found in Earth's crust.

b. Manufactured

Magnets are usually made of iron, steel, cobalt, nickel, or alnico (an alloy including aluminum, nickel, and cobalt.)

Manufactured magnets can be temporary or permanent.

What are some examples of a temporary magnet? A permanent magnet?

How can we make a temporary magnet? A permanent magnet? **(G-60, 61)**

2. Properties of magnets

a. The poles

Magnets have two unlike magnetic poles, one north-seeking and the other south-seeking. If a magnet is cut in half, two magnets are formed, each having a north-seeking and a south-seeking pole.

Where is a magnet the strongest? **(G-62)**

How can we demonstrate that magnets have two unlike poles? **(G-63)**

b. Attraction and repulsion between magnets

The like poles of two magnets will repel each other, while their unlike poles will attract.

How can we show that like poles repel each other and unlike poles attract each other? **(G-64)**

c. The magnetic field of a magnet

(1) A magnetic field surrounds a magnet. A magnetic field has a characteristic shape and direction that depends on the magnet producing it.

How can we demonstrate the presence of a magnetic field? **(G-65,66)**

How can we demonstrate the interaction of two magnetic fields? **(G-67,68)**

How does the strength of a magnetic field vary with distance from the magnet? **(G-69)**

(2) Since Earth has a magnetic field, the poles of a free-floating magnet will line up with the direction of Earth's magnetic field.

What happens to a free-floating magnet? Why? **(G-70)**

d. Materials attracted by magnets

A magnet attracts iron, cobalt, and nickel, and alloys of these three elements.

3. A model for magnetism

a. Composition of magnetic materials

Magnetic materials can be thought of as consisting of many small magnets.[2]

b. Random or regular arrangement

In an unmagnetized magnetic material, the small magnets are arranged randomly. In a magnetized material, many of the small magnets are lined up with the north poles facing in one direction and the south poles facing in the opposite direction. When more of these small magnets are lined up, the magnetized material becomes a stronger magnet.

How is a magnetic material magnetized? **(G-61)**

B. ELECTRICITY

Electricity results from the movement of electric charge.[1]

1. Static electricity

Static electricity results when objects gain or lose an electric charge.

What does the word "static" mean? Why is this word applied to this kind of electricity?

What are some effects of static electricity? **(G-71)**

How can static electricity be detected? **(G-72)**

a. Electric charge

(1) An electron has a negative charge. A proton has a positive charge.

(2) An uncharged object has an equal number of positive charges and negative charges.

(3) A charged object has gained or lost negative charges. The number of positive charges and negative charges are unequal.

b. Electric force

(1) Charged objects exert a force on other charged objects. Objects with like charges repel each other. Objects with unlike charges attract each other.

How are electric charges similar to magnetic poles?

How can we demonstrate that charged objects exert a force? **(G-73)**

(2) The amount of electric force between charged objects increases as the amount of charge on either object increases, and decreases as the distance between the objects increases.

c. Production of static electricity

(1) Conduction occurs when a charged object touches another object. Negative charges are transferred between the objects.

How can static electricity be produced? **(G-74)**

How is static electricity produced by conduction? **(G-75)**

(2) Induction occurs when a charged object is brought near an uncharged object. The negative charges in the uncharged object are rearranged.

How is static electricity produced by induction? **(G-76)**

2. Current electricity

Current electricity results when electric charges flow through a conductor.

How is current electricity different from static electricity?

a. Conductors and insulators

(1) Electric charges move easily through conductors. Conductors can be solids, liquids, or gases. Metals are good conductors. In metals, the electric charges that move are electrons.

What are some examples of electrical conductors and insulators? **(G-77)**

(2) Electric charges do not move easily through insulators. Some good insulators are rubber, mica, and dry air.

b. Electric current and circuits

(1) Electric current flows through an electric circuit. Current flows only between regions of unlike charge.

(2) A simple electric circuit consists of a conducting wire, a source of electric charges, and a resistance. A circuit may be open or closed.

In a typical electric circuit, what supplies the electric charges?

What might be the resistance?

c. Characteristics of electric current

(1) Voltage[31]

(a) Voltage in an electric circuit is analogous to pressure in a water pipe.

(b) The unit of measure is the volt. A voltmeter measures voltage.

(2) Flow of current

(a) Current is the number of electric charges flowing through a circuit in a unit of time.

(b) The unit of measure is the ampere. An ammeter measures current.

(3) Resistance

(a) Resistance measures how difficult it is to move electric charges through a circuit.

(b) The unit of measure is the ohm.

(4) Ohm's law

Amount of current, voltage, and resistance are related. The amount of current can be determined by dividing the voltage by the resistance.

How can voltage be measured? **(G-78)**

How is a voltmeter connected in an electric circuit?

How can current be measured? **(G-79)**

How is an ammeter connected in an electric circuit?

What are some factors that increase the resistance in a circuit? **(G-80)**

What is the relationship between voltage, current, and resistance? **(G-81)**

d. Types of electric circuits

(1) Series circuit

(a) A series circuit has only one conducting path.

(b) Any break in a series circuit stops the flow of electric charges in the entire circuit.

(c) The current is the same in all parts of a series circuit.

(2) Parallel circuits

(a) A parallel circuit has two or more conducting paths.

(b) A break in one branch of a parallel circuit does not stop the flow of current in other branches.

(c) The current can be different in different branches of a parallel circuit.

(d) The voltage is the same across each branch of a parallel circuit.

What are some characteristics of a series circuit? **(G-82)**

How is the voltage affected when dry cells are connected in series? **(G-83)**

What are some characteristics of a parallel circuit? **(G-84)**

How does the total voltage of two dry cells hooked in parallel compare to the voltage of a single dry cell? **(G-85)**

What types of circuits are used in your home?

e. Types of electric current

(1) Direct current

(a) When a circuit carries direct current, electric charges flow in one direction.

(b) Dry cells or batteries produce direct current.

(2) Alternating current

(a) When a circuit carries alternating current, the

How can we produce direct current? **(G-86, 87)**

How does a dry cell work?

What is the difference between alternating and direct current?

electric charges continuously change their direction of flow.

(b) Electric generators produce alternating current. Most of the electricity used in homes and businesses is in the form of alternating current.

How is alternating current produced? **(G-88)**

f. Measuring electric power and electric energy

(1) Electric power

(a) Power is the amount of energy delivered in a unit of time.

(b) Electric power is calculated by multiplying the voltage in a circuit by the current. The unit of electric power is the watt (W) or kilowatt (kW).

What are the wattages of some common household appliances?[32]

How can electric power be calculated? **(G-89)**

(2) Electric energy

Use of electric energy is measured in kilowatt-hours (kWh).

How is our use of electric energy measured? What is an electric meter?

C. THE RELATIONSHIP BETWEEN MAGNETISM AND ELECTRICITY

1. Motion in a magnetic field can produce electricity

When a magnet is moved inside a coil of wire, or when a coil of wire is moved in a magnetic field, an electric current is produced.

2. Electricity can produce magnetism

When an electric current flows through a wire, a magnetic field surrounds the wire.

What does a small electric current do to the magnetic needle of a compass? **(G-90)**

D. MORE ON MAGNETISM AND ELECTRICITY

1. Magnetism

a. Generation of electricity

Generators are machines that move magnets in coils of wire. We use large generators to produce electricity for our everyday use.

How is electricity generated?

b. Determining direction

(1) Compasses, which allow us to tell direction on Earth's surface, are based upon magnetic properties.

How does a compass work?

(2) Some organisms have magnetite in their bodies, suggesting that they use Earth's magnetic field to help them navigate.

What organisms migrate (or travel long distances) and might have magnetite in their bodies?

2. Electricity

a. Generation of magnetism

When a piece of iron is placed inside a coil of wire and current flows through the wire, an electromagnet is produced. Giant electromagnets move large loads for us.

How are electromagnets used in industry and business?

b. Benefits from electricity

Modern society depends on electricity. Electricity provides us with many comforts in our homes, and with the energy to perform many tasks in industry.

Could we do without electricity in our modern society? Why or why not?

c. Safety with electricity

Electricity is dangerous and can injure or kill living organisms. Our everyday use of electricity requires us to observe safety rules.

What are some dangers in using electricity?**(G-91)**

(1) Fuses and circuit breakers

Fuses and circuit breakers protect us from fires that can be caused by overloaded circuits.

What is an overloaded circuit? Why is it dangerous?

How does a fuse work?**(G-92)**

(2) Grounding

(a) Grounding uses a conductor to connect an object to the earth, which can absorb excess electrons without becoming dangerously charged.

Why is grounding important? **(G-93)**

How does the earth act as a ground?

What is the function of a lightning rod?

(b) Electrical devices should be grounded to prevent electrical shock.

What are some objects which are grounded?

What are some safety rules to follow when using appliances?

VIII. NUCLEAR ENERGY

A. RADIOACTIVITY

1. Radioactive elements

Some elements are naturally radioactive. An atom of a radioactive element has an unstable nucleus. As the nucleus breaks apart, it gives off energy in the form of radiation, including alpha and beta particles and gamma rays. After the nucleus breaks apart, a different atom remains behind. This atom is of a different element.

How does nuclear energy differ from other forms of energy?

How can we differentiate between alpha and beta particles and gamma rays?**(G-94)**

2. Radioactive isotopes

A radioactive element may exist in two or more different forms, called radioactive isotopes.[33]

3. Radioactive decay

A sample of a radioactive element is said to decay as it breaks down into a different element.

4. Half-life of a radioactive element

The half-life of a radioactive element describes how long it takes for half of a sample of the element to decay. Each radioactive element has a specific half-life which can vary from less than a second to billions of years.

How can we demonstrate the half-life of a radioactive element? **(G-95)**

5. Background radiation

Some radioactive elements occur on Earth, and some radioactivity reaches Earth from space. Gamma and cosmic rays from these sources are called background radiation, a level of radiation that occurs naturally. Gamma rays and some cosmic rays are electromagnetic waves and form a portion of the electromagnetic spectrum.

6. Detection of radioactivity

Radioactivity can be detected by photographic film, electroscopes, and Geiger counters.

How does a Geiger counter work? **(G-96)**

How is a Geiger counter adjusted to account for background radiation?

B. NUCLEAR REACTIONS

Nuclear energy is released during a nuclear reaction. A nuclear reaction occurs when the nucleus of an atom changes. Tremendous amounts of energy can be released during a nuclear reaction.

1. Radioactive decay

Radioactive decay is a nuclear reaction.

How does uranium 238 decay? **(G-97)**

2. Fission

a. Splitting of the atom

Some radioactive elements can undergo fission. When fission occurs, the nucleus of an atom splits into smaller nuclei. A neutron usually begins the fission process. Fission does not usually occur spontaneously.

b. Chain reactions

When the products of a nuclear reaction in one nucleus can start a reaction in other nuclei, a chain reaction occurs. A chain reaction may be controlled or uncontrolled.

How can we demonstrate an uncontrolled chain reaction? **(G-98)**

What is an example of an uncontrolled chain reaction? A controlled chain reaction?

3. Fusion

Some elements can undergo fusion. When fusion occurs, nuclei join together to form a larger nucleus. Fusion requires very high temperatures and occurs naturally only in stars.

C. MORE ON NUCLEAR ENERGY

1. Beneficial effects

a. From radioactive isotopes

Radioactive isotopes are used in medicine to diagnose disease and destroy cancer cells; in industry to provide quality control; and in scientific research to investigate chemical reactions and biological systems, to date fossils and ancient materials, and to create new elements.

What are some uses of radioactive isotopes? **(G-99)**

How are radioactive isotopes used in medical diagnosis?

How are radioactive isotopes used in quality control? **(G-100)**

How is the half-life of a radioactive isotope used to date fossils?

b. From fission

Nuclear power plants use fission to provide us with electrical power. Useful radioactive isotopes are also produced in nuclear power plants.

2. Harmful effects

a. Uncontrolled radiation

Uncontrolled radiation from radioactive materials is dangerous. It can cause changes in the nucleus and chromosomes of cells, can injure or kill living organisms and can cause deformed offspring.

b. Sources of harmful effects

(1) Overexposure to radiation

Humans always receive a small amount of radiation from background sources. The harmful effects of radiation occur when large doses of radiation are received or when small doses of radiation (larger than background radiation) are received over a long period of time.

(2) Nuclear weapons

Exploded nuclear bombs produce large amounts of uncontrolled radiation.

3. Special concerns

a. Nuclear power plant safety

Radiation from a nuclear power plant must be rigidly controlled. A serious accident at a nuclear power plant could result in the release of large amounts of radiation.

What are some of the issues concerning nuclear energy?[34] **(G-101)**

b. Transport and disposal of nuclear waste

Radioactive waste materials from all uses of nuclear energy are a potential source of uncontrolled radiation. These wastes must be safely transported and disposed of.

Why is the disposal of nuclear wastes with very long half-lives a serious, unsolved problem?

c. Increased use of radioactive isotopes

As use of non-natural radioactive isotopes increases in medical treatment and in business and industry, special care must be taken to ensure that these isotopes are carefully handled and disposed of so that people are not overexposed to radiation.

4. Fusion

At present, humans can produce uncontrolled fusion reactions in the form of thermonuclear bombs. Fusion reactions can be controlled, but more energy is required to achieve fusion than the reactions yield.

What are some current developments in fusion research? **(G-102)**

FOOTNOTES

[1] When the forces on an object are balanced, the sum of the forces is zero. Whether or not the forces are balanced must be deduced from a study of the entire system in which the forces are acting.

[2] Weight is dependent on mass. The weight of an object with a constant mass can change if the object is attracted by another object with a different mass. The mass of the moon is less than the mass of Earth. Thus, the moon's gravitational force on an object is less than that of Earth's on the same object. Humans weigh less, therefore, on the moon than on Earth.

[3] A table of the units used in this publication is given in Appendix B.

[4] The term velocity, which is the speed of an object in a particular direction, is not used in this publication. For students at this level, the term speed may be substituted for velocity.

[5] A table of the formulas used in this publication is given in Appendix B. Students are not expected to memorize the formulas, but should be able to apply them.

[6] Actually, work is done only when the force (or a component of the force) is applied in the direction of motion of the object.

[7] Levers employ the principle of the turning effect produced by a force about a pivotal point. The torque, or turning effect, is the product of the perpendicular force and the pivotal arm length. Many combinations of forces and pivotal arm lengths can be multiplied together to obtain a given product. The lever can change the relative values of force and distance to those desired.

[8] Students should be able to locate the fulcrum, the effort force, and the resistance force on common levers, and to compare the relative positions of fulcrum, effort force, and resistance force given different kinds of levers.

[9] Since most levers have very little friction, the actual mechanical advantage is very close to the ideal mechanical advantage.

[10] Weight always acts in a downward direction toward the center of Earth. When an object is resting on an inclined plane, the weight is resolved into two smaller components. One of these components is acting in a direction that is parallel to the inclined surface. The other component is at right angles to the incline and is fully supported by the surface of the plane. Thus, the effort to move the object along the plane can be relatively small because it only has to overcome the component of weight that is parallel to the incline. In this way, an inclined plane also changes the direction of the force applied.

[11] The mechanical advantage of a complex machine is calculated by multiplying the mechanical advantages of the simple machines which comprise it. Thus, if a lever with a MA of 10 is used to move an object up an inclined plane with a MA of 15, the combined mechanical advantage of the complex machine is 150.

[12] Although there are individual variations, a sound can be heard by humans if its frequency is between 20 vibrations per second and 20,000 vibrations per second. If the frequency is below 20 vibrations per second, the sound is called subsonic. Sounds with frequencies over 20,000 vibrations per second are known as ultrasonic sounds. A dog whistle is an example of a device that produces ultrasonic sound.

[13] One application of the Doppler effect is speed-detecting radar.

[14] Interesting applications of the reflection of sound waves include whispering galleries, parabolic microphones to pick up faraway sounds or individual sounds in a crowd, and sonar.

[15] In 1940, the Tacoma Narrows Bridge collapsed in high winds. The bridge began oscillating in response to the frequency of the wind as a result of the lift forces produced as the wind blew across the bridge's surface. Resonance was established by the periodic interruption of the wind by the motion of the bridge.

[16] When resonance occurs, the amplitude of the sound increases. This can be likened to pushing a child on a swing. A small force applied at the proper time will increase the amplitude of the swing. Resonance is used in some musical instruments. In the sitar, some sets of strings are not played, but add to the sound of the instrument through resonance.

[17] Below are some approximate speeds of sound through different mediums: air = 340 m/sec; water = 1,454 m/sec; wood = 3,828 m/sec; iron = 5,103 m/sec; and stone = 5,971 m/sec.

[18] Our individual perceptions of what constitutes good music will often determine or alter the effect of the music. Therefore, the same piece of music may have varying and even opposite effects on different people.

[19] The speed of light in a vacuum is approximately 300,000,000 m/sec.

[20] Although electromagnetic radiation has characteristics of both particles and waves, the properties of electromagnetic radiation appropriate for students at this level can be explained in terms of waves.

[21] Refer to Activity G-32 for a diagram of the electromagnetic spectrum.

[22] See Activity G-32 for a diagram of the visible light spectrum.

[23] Lenses may be studied in greater detail if the topic is appropriate to the students' level of understanding.

[24] The wavelengths of light which are reflected from a surface depend upon the material of the surface. If the atoms in the surface accept energy from some of the incoming wavelengths of light, those wavelengths are absorbed. The other wavelengths are reflected, and they produce the characteristic color of the surface. The dyes and pigments used to color surfaces are made from substances whose atoms reflect and absorb light in particular ways, thus producing colors.

[25] The exception to this is when a material changes phase. During phase change, the potential energy of the particles increases as they become "repositioned" while their kinetic energy remains constant, as indicated by a constant temperature.

[26] For any substance, heat transfer is actually calculated by multiplying the mass, the change in temperature, and the specific heat of the substance. The specific heat of water is 1.0 cal/g°C, and need not be included in the equation used by students at this level.

[27] The food Calorie (which you may often see written with a lower case c) is actually a kilocalorie (kcal).

[28] For more on insulation, heat loss, and energy conservation, see *Block I, Energy: Sources and Issues*.

[29] If students have previously been taught the understandings from *Block H, The Chemistry of Matter*, this can be explained in terms of atomic structure and electron spin.

[30] At this point, if students have not previously been taught the understandings from *Block H*, they should be given a brief background on atomic structure.

[31] At this level, no distinction need be made between electromotive force, potential difference, and voltage.

[32] If students are asked to survey appliance wattages as a homework assignment, remind them of the safety procedures to be used with appliances.

[33] For more information on isotopes, see *Block H, The Chemistry of Matter*.

[34] For more information on nuclear energy issues, see *Block I, Energy: Sources and Issues*.

APPENDIX A — LEARNING ACTIVITIES

G-1. BALANCED AND UNBALANCED FORCES
(1, 14)

PURPOSE:

To demonstrate the differences between balanced and unbalanced forces.

MATERIALS:

rubber band
ball or other spherical object

PROCEDURE:

(1) Push against a wall.
(2) Hold a stretched rubber band.
(3) Observe the ball sitting on a table.
(4) Push the ball, then tap the rolling ball into a circular path.
(5) Which of the above steps illustrate balanced forces? Unbalanced forces? Demonstrate some other examples of balanced and unbalanced forces.

RESULTS:

(1), (2), and (3) demonstrate balanced forces, since no change in shape or motion has occurred. (4) demonstrates an unbalanced force.

G-2. MASS AND WEIGHT
(5, 13, 14)

PURPOSE:

To observe the relationship between mass and weight.

MATERIALS:

spring scale calibrated in newtons
set of gram masses

PROCEDURE:

(1) Use the spring scale to determine the weights of the masses.
(2) Record the weights in a table.
(3) Graph the relationship between mass and weight.

RESULTS:

As mass increases, weight increases.

G-3. FRICTION
(1, 4, 5, 14)

PURPOSE:

To demonstrate that friction is a force.

MATERIALS:

grooved ruler
meter stick
marble
a book about 2 cm thick
clock or watch with a second hand

PROCEDURE:

(1) Place one end of the ruler on the book and the other end on the floor.

(2) Let the marble roll down the groove of the ruler.

(3) Mark how far the marble rolls from the lower end of the ruler in 2 seconds. Measure this distance and record.

(4) Repeat this procedure at least three times. Find the average distance rolled in 2 seconds by adding all the distances measured and dividing by the total number of measurements.

(5) Find the average speed of the marble by dividing the average distance rolled by the time taken to travel that distance.

(6) Repeat the entire procedure, this time determining how far the marble rolls in 4 seconds. Find the average speed.

(7) Compare the results for the two procedures.

RESULTS:

The speed of the marble over the 4-second interval will be slower because of the force of friction.

G-4. SPEED
(1, 4, 5, 14)

PURPOSE:

To determine the speed of an object.

MATERIALS:

a small moving toy (such as a wind-up toy or a battery-operated toy)
meter stick
clock or watch with a second hand

PROCEDURE:

(1) Mark a spot from which the toy is to start.

(2) Start the toy and let it run for a given number of seconds.

(3) Measure the distance traveled during that time (in centimeters).

(4) Determine the speed of the toy by dividing the distance traveled by the time taken to travel that distance.

(5) Repeat several times using the same or different time periods.

RESULTS:

For the same time period, the speeds should be approximately the same. Speeds should be expressed in centimeters/second.

G-5. INERTIA
(1, 2, 14)

PURPOSE:

To observe inertia.

MATERIALS:

one uncooked egg

PROCEDURE:

(1) Carefully spin the egg on a hard surface.

(2) Momentarily stop the egg from spinning, then quickly release it.

(3) Observe and explain what happened.

RESULTS:

Because of inertia, the liquid contents of the egg continue to spin when the egg is momentarily stopped. This causes the egg to resume spinning when released.

G-6. INERTIA AND MASS
(1, 4, 5, 14)

PURPOSE:

To demonstrate the relationship between mass and inertia.

MATERIALS:

wheeled cart
0.5 kilogram mass or other large mass
spring scale calibrated in newtons

PROCEDURE:

(1) Attach the empty cart to the spring scale. Use the spring scale to pull the cart across a table or the floor. Record the force needed to:
- just start the cart moving
- keep the cart moving once it is in motion.

(2) Repeat (1) two more times. Average the three trials for each force.

(3) Place the half-kilogram mass on the cart. Repeat (1) and (2).

(4) For either the empty or loaded cart, how does the force needed to start the cart compare with the force needed to keep the cart moving?

(5) How do the forces needed to just start the cart moving compare in each case?

(6) How do the forces needed to keep the cart moving compare in each case?

RESULTS:

With either the empty or loaded cart, the force needed to start the cart is greater than the force needed to keep it moving because of the inertia of the cart at rest.

The force required to start or keep the loaded cart moving is greater than that for the empty cart. Inertia increases as mass increases. There is less difference in the forces needed to keep each cart moving than there is in the forces needed to start each cart moving.

G-7. ACTION — REACTION
(1, 2, 4, 14)

PURPOSE:

To demonstrate the existence of the reaction force.

Part A (Teacher Demonstration)

MATERIALS:

a block of wood approximately 5 5 × 10 × 12 5 cm
thin wire (#30)
four screw eyes
heavy rubber band
two nails
string
bent nail or brad
small heavy balls of different sizes (such as a heavy pendulum bob)
matches

PROCEDURE:

(1) Prepare the platform as shown in the diagram. Suspend it with thin wire from the four screw eyes in the corners.

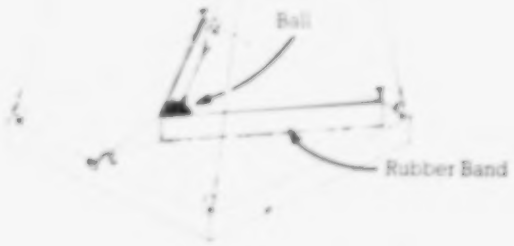
(2) Attach the heavy rubber band to the two nails near one end of the platform and hold it back with a loop of string knotted over the bent nail.

(3) Place a ball in the pocket formed by the rubber band.

(4) Burn the string by holding a lighted match below the bent nail. (**Caution:** Make sure that students or breakable items are not in the path of the ball.)

(5) Observe what happens.

(6) Repeat with balls of different sizes.



RESULTS:

The platform will recoil when the ball is shot from it. Balls of greater mass will produce more recoil. Other examples of action and reaction include the writhing of a garden hose (when water is shooting from it) and the recoiling of a rifle (when it is fired).

Part B

MATERIALS:

balloon

PROCEDURE:

(1) Blow up the balloon.

(2) Let go of the balloon. Observe what happens and record.

(3) Identify the action force.

(4) Identify the reaction force.

(5) How is what happened with the balloon similar to how a rocket engine works?

RESULTS:

The action force is the air being forced from the balloon's opening. The reaction force is the movement of the balloon in the opposite direction. A rocket engine works on this same principle. As exhaust gases are propelled from the rocket in one direction, the rocket moves in the opposite direction.

Part C (Teacher Demonstration)

MATERIALS:

heavy fishing line
250 ml Erlenmeyer flask
two-hole stopper
glass tubing
heat source
water

PROCEDURE:

(1) Set up the apparatus as shown in Diagram A.

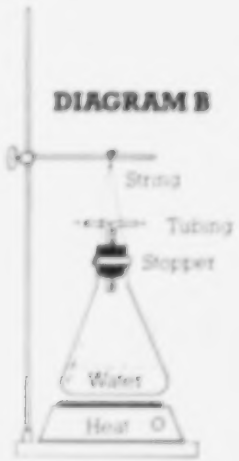
(2) Hang the flask over the heat source as shown in Diagram B.

(3) Ask students to observe what happens and to identify:

- the action force
- the reaction force

DIAGRAM A

DIAGRAM B



RESULTS:

As the water heats and steam is forced from the glass tubing, the flask begins to turn. The action force is the steam being forced from the tubing. The reaction force is the flask turning.

G-8. MOTION AND SAFETY

(1, 2, 4, 8, 9, 18)

PURPOSE:

To relate the laws of motion to everyday life.

MATERIALS:

wheeled cart to represent an automobile
masking tape to represent a safety belt
inclined plane
small stuffed animal to represent the automobile's passenger
immovable object (wall, heavy weight) to represent a tree, a bridge abutment, or parked car

PROCEDURE:

(1) Place the passenger in the cart. Roll the cart down the inclined plane into the immovable object. The speed should be great enough to throw the passenger.

(2) Observe what happens. Why did the unrestrained passenger keep moving? What would happen to a real passenger in a real car? Would the passenger be injured?

(3) Repeat (1) at slow and fast speeds. What happens to the passenger at slower speeds? At faster speeds? Why?

(4) How could you use the masking tape to keep the passenger from being thrown from the cart?

(5) Repeat (1). What happens to the passenger now? Why? What would happen to a real passenger in a real car? Would the passenger be injured?

RESULTS:

Without a "safety belt," the "passenger" continues to move forward as a result of inertia. In a real car, the passenger would hit the windshield and most likely receive head injuries. With the "safety belt," the "passenger" is restrained and does not continue to move forward. The safety belt stops the passenger's inertia due to motion. Students should realize that an understanding of the basic concepts of physical science will enable them to function better in their environment.

Note: *Seat Belt Science: Activities for General Science* is a packet of materials produced by the National Science Teacher's Association. The packet includes a short film of an automobile (with dummy passengers) crashing at a speed of 35 miles per hour. Students can perform several activities based on this film.

One packet is available to each New York State school district through attendance at a seat belt science workshop given by the Bureau of Science Education. For more information, contact the Bureau of Science Education, Room 302 EB, NYS Education Department, Albany, NY 12234.

G-9. CALCULATING WORK

(4, 5, 7, 12)

PURPOSE:

To practice calculating the amount of work done in lifting an object.

MATERIALS:

spring scale calibrated in newtons
meter stick
several objects (ranging in weight from 2 to 5 newtons)

PROCEDURE:

(1) Measure the distance from the floor to the top of a desk.

(2) Attach one object to the spring scale and slowly raise the object from the floor to the top of the desk.

(3) Record the force required to lift the object. (Always read a spring scale at eye level.)

(4) Calculate the work done in newton-meters by using the equation: Work = Force × Distance.

(5) Repeat the procedure for the other objects.

(6) Repeat the procedure, but this time drag the objects rather than lift them.

RESULTS:

The greater the weight of an object, the greater the amount of work done in lifting or dragging it a given distance. The force required to drag an object is less than that required to lift it. Therefore, less work is done when an object is dragged a given distance than when it is lifted the same distance.

G-10. POTENTIAL ENERGY
(5, 12, 14, 17)

PURPOSE:

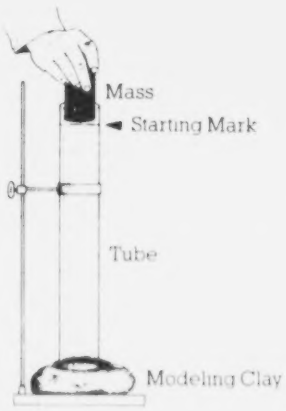
To determine the relationship between the potential energy of an object and the amount of work it can do.

MATERIALS:

modeling clay (soften by working it a few minutes)
two cylindrical masses with the same cross-sectional area, but different masses (Test different masses to determine which give the best results.)
large-diameter plastic tube or a cardboard mailing tube 0.5 to 1 meter long
ring stand and clamp
spring scale calibrated in newtons
meter stick

PROCEDURE:

(1) Shape a large piece of clay as shown in the diagram and place it as shown.
(2) Record the weight of each cylinder.
(3) Measure the height of the tube.
(4) Calculate the potential energy of each cylinder by multiplying its weight by the distance it has been lifted (the height of the tube).
(5) Hold one cylinder so that its bottom is just inside the top edge of the tube. Drop the cylinder through the tube. Record the depth of the depression it makes in the clay.
(6) Repeat (5) using the other cylinder.
(7) Compare the depths of the indentations made by both cylinders.



RESULTS:

The heavier cylinder had more potential energy and made a greater indentation in the clay. Therefore, the greater the potential energy, the greater the amount of work done.

G-11. KINETIC ENERGY
(1, 4, 14, 17)

PURPOSE:

To determine the effect of mass and speed on kinetic energy.

MATERIALS:

string
empty spool of thread
rubber stoppers of different sizes
dowels

PROCEDURE:

(1) Place a string through the empty spool and stretch the string across the classroom.

(2) Make different-sized mallets by placing the stoppers on the dowels.

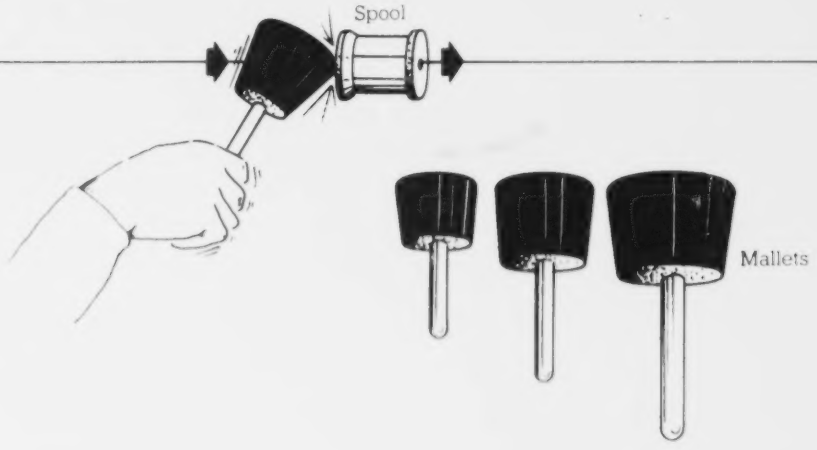
(3) Strike the spool with different mallets moving at the same speed.

(4) Strike the spool with the same mallet moving at different speeds.

(5) Record and analyze the results.

RESULTS:

The greater the mass of the rubber mallet and the greater its speed as it hits the spool, the greater the kinetic energy gained by the spool.



G-12. POTENTIAL AND KINETIC ENERGY

(1, 2, 4, 14)

PURPOSE:

To observe the relationship between potential and kinetic energy.

MATERIALS:

pendulum

PROCEDURE:

(1) Start the pendulum.

(2) At what point is its energy entirely potential? Entirely kinetic? A combination of the two?

(3) Why does the motion eventually cease?

(4) Draw and label a diagram showing where the pendulum has potential energy and where it has kinetic energy.

RESULTS:

The pendulum has only potential energy at the height of its swing. It has only kinetic energy at the lowest point of its swing. At any point in between, it has both potential and kinetic energy. The pendulum's motion eventually ceases because of friction between it and the surrounding air.

G-13. FORMS OF ENERGY

(1, 2, 14)

PURPOSE:

To show how different forms of energy are used in daily activities.

Things I Use Every Day	Forms of Energy
1. automobile	electrical chemical mechanical
2. typewriter	mechanical
3.	

PROCEDURE:

(1) Construct a table like the one shown.

(2) In the first column, list things that you use every day. In the second column, list the forms of energy used by the device.

G-14. THE WHEEL

PURPOSE:

To find out more about the invention of the wheel.

MATERIALS:

the article, "Birth of the Wheel" (Appendix C-1)

PROCEDURE:

After reading "Birth of the Wheel," place a check next to each of the statements with which you agree. When you have reacted to all of the statements, compare your responses with those of your classmates. Where there are differences, discuss the reasons for those differences. Try to understand the positions taken by those who differ with you. Where you have the same responses, discuss them to see if your agreements are based on similar or different reasons.

____1. The wheel is the greatest invention of humans.

____2. The first known wagon could not turn.

____3. A wheel reduces friction as much as 100 times.

____4. The wheel was invented by the Sumerians.

____5. Modern transportation is based on the wheel.

____6. About 2000 BC, wheeled vehicles were attached to horses.

____7. The wheel is more important than the horse.

____8. The use of spokes made the wheel lighter and more maneuverable.

____9. The Celts made the first wagons with wheels that could turn.

____10. Wheels are still being improved.

RESULTS:

The questions are intended to encourage students to react critically to the article. There are no right or wrong answers: a student's response depends on whether the student accepts the information given in the article or not.

G-15. FUNCTIONS OF MACHINES

(1, 2, 8, 14)

PURPOSE:

To show why we use machines.

PROCEDURE:

(1) List machines used in everyday life.

(2) Explain how each machine makes some tasks seem "easier" or "faster" to accomplish.

(3) List some tasks you do that would be very hard or impossible to do without a machine.

RESULTS:

One machine cited by a student might be an electric mixer which whips eggs faster than if they were whipped with a spoon.

G-16. SOME FUNCTIONS OF A PULLEY

(4, 5, 9, 14, 17)

PURPOSE:

To demonstrate the different functions of fixed and movable pulleys.

MATERIALS:

fixed pulley
movable pulley
a support
an object to lift
spring scale calibrated in newtons
string
meter stick

PROCEDURE:

(1) Attach the object to the movable pulley and weigh. Record the weight.

(2) Attach the fixed pulley to a support.

(3) As shown in Diagram A, gently pull down on the spring scale, lifting the object and movable pulley. Read the spring scale at eye level and record the reading. (The movable pulley is lifted along with the object so that the weight lifted here is the same as the weight lifted using a movable pulley.)

(4) Set up the movable pulley as shown in Diagram B. Predict how much force will be needed to lift the object.

(5) Gently lift the object with the movable pulley. (Note that the total weight lifted is the weight of the object plus the weight of the movable pulley.) Record the force required to lift the object with a movable pulley.

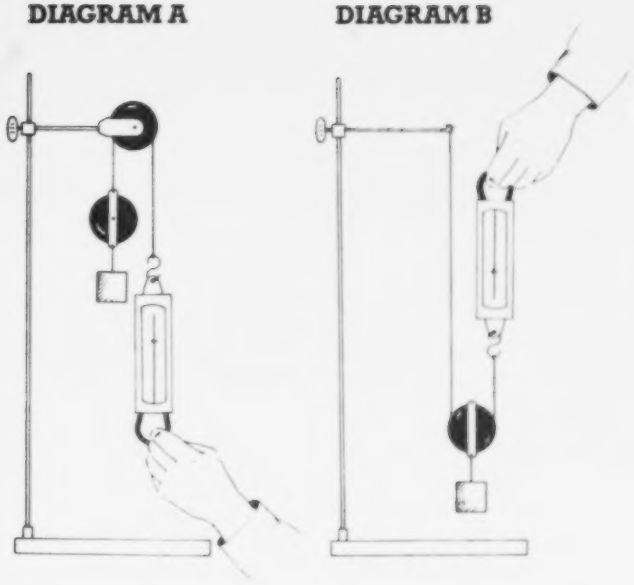
(6) Compare the force needed to lift the object in each case.

(7) Use the fixed pulley to lift the object 50 cm. How far did you have to move the spring scale? How much work was done? (You can obtain the force from (3).)

(8) Use the movable pulley to lift the object 50 cm. How far did you have to move the spring scale? How much work was done? (You can obtain the force from (5).)

(9) Compare the distances the spring scale moved, the forces needed to lift the object, and the work done with each pulley.

DIAGRAM A **DIAGRAM B**



RESULTS:

The force needed to lift the object with the movable pulley is about half that needed with the fixed pulley. The force needed with the fixed pulley is slightly larger than the weight of the object and the movable pulley because of friction. The fixed pulley changes the direction of the force. The spring scale is moved 50 cm with the fixed pulley and 100 cm with the movable pulley. With the movable pulley, although half the force is needed, it must be moved twice as far. The amount of work done with each pulley is the same.

G-17. LEVERS

(1, 4, 5, 9, 14, 16)

PURPOSE:

To explore the relationship between force and distance in one type of lever.

MATERIALS:

500 g mass
string
scissors
meter-stick lever (See diagram.)
lever support
spring scale calibrated in newtons

PROCEDURE:

(1) Hang the 500 g mass from the scale. Read and record the force registered on the scale.

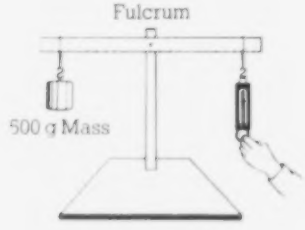
(2) Cut two pieces of string 15 cm in length. Tie each piece to make two identical loops.

(3) Set up the apparatus as shown. Slip a loop onto the lever from each end. Place one loop 40 cm from the fulcrum and hang the 500 g mass from it. Place the other loop 40 cm from the fulcrum and hang the scale from it. Pull down on the scale. Read and record the force needed to balance the 500 g mass.

(4) Move the loop with the scale to a position 30 cm from the fulcrum. Read and record the force needed to balance the 500 g mass.

(5) Repeat with the scale 20 cm from the fulcrum.

(6) Analyze your results and predict where you would apply force on the lever so that the least possible force balances the 500 g mass. Test your prediction. Was it correct or incorrect? Why?



RESULTS:

As force is applied farther from the fulcrum, less is required to balance the mass.

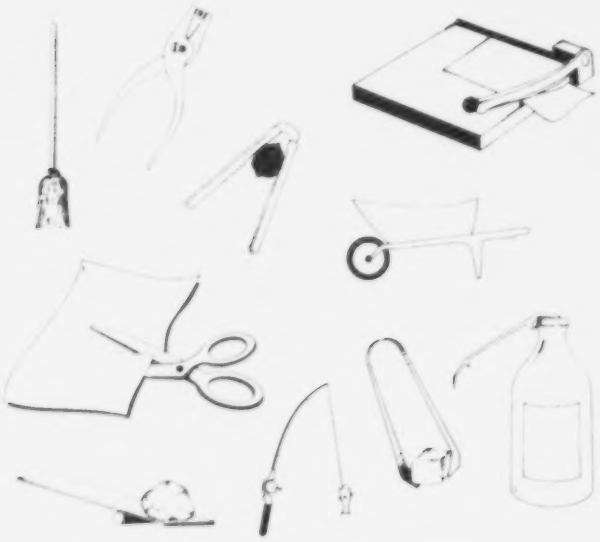
G-18. CLASSES OF LEVERS
(1, 2, 14, 17)

PURPOSE:

To locate the relative positions of fulcrum, resistance, and effort on different kinds of levers, and to recognize the kinds of levers based on these relative positions.

MATERIALS:

different kinds of levers (brought from home and borrowed from home economics and industrial arts classrooms)



PROCEDURE:

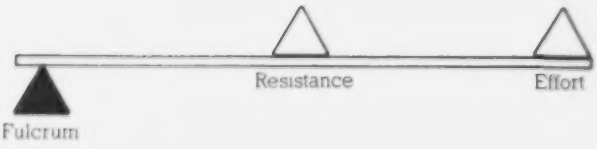
(1) Examine each lever and locate its fulcrum, resistance arm, and effort arm. Use each lever. Does the lever (a) change the direction of the force, (b) multiply the force, (c) multiply speed, (d) multiply distance, or (e) do a combination of the above?

(2) Sketch each lever and label the fulcrum, resistance arm, and effort arm.

(3) Compare the relative positions of the labelled parts. Based on these relative positions, how many different kinds of levers are there? Draw each kind, labelling its parts.

RESULTS:

There are three classes of lever, as shown. Each class has a particular function in changing the direction of the force, multiplying the force, and/or multiplying the speed and/or distance.



G-19. RELATIONSHIP OF THE HEIGHT OF AN INCLINED PLANE TO THE EFFORT FORCE

(1, 9, 10, 12, 14, 16)

PURPOSE:

To demonstrate the relationship between the height of an inclined plane and the effort force required to lift an object.

MATERIALS:

inclined plane
support stands of different heights
cart or roller skate
meter stick
spring scale calibrated in newtons
string

PROCEDURE:

(1) Formulate a hypothesis that states the relationship between the height of an inclined plane and the effort force required to pull a cart up it.

(2) Design an investigation to test the hypothesis.

(3) Carry out the investigation and record all results.

(4) Analyze the results and state your conclusion.

RESULTS:

Students might try an investigation similar to the following:

(a) Lay the inclined plane against a support 10 cm high.

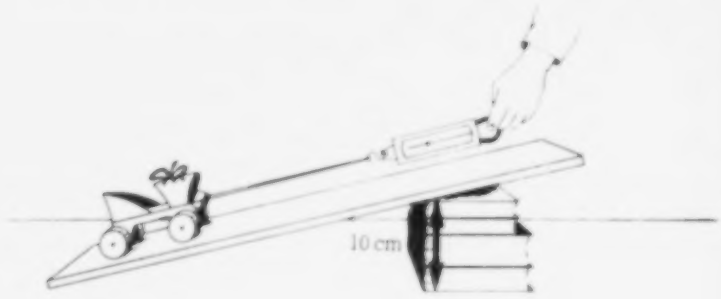
(b) Gently pull the cart up the plane with the spring scale.

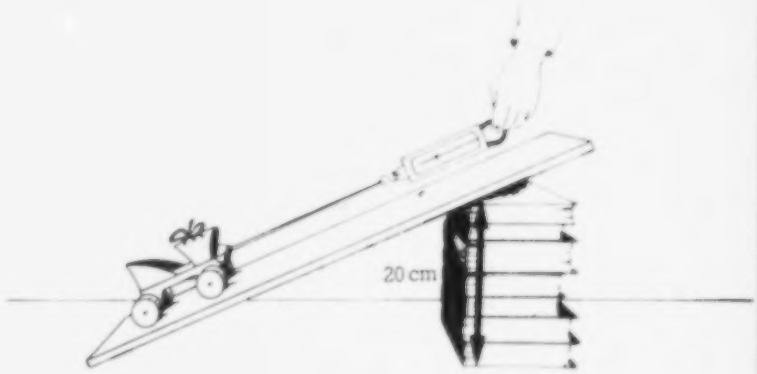
(c) Record the force required to pull the cart up the plane.

(d) Repeat the above procedure raising the plane 20 cm from the ground, then 30 cm, then 40 cm.

(e) Make sure all variables except the height of the plane are controlled.

As the height of the inclined plane increases, the effort force also increases.





G-20. CALCULATING MECHANICAL ADVANTAGE AND EFFICIENCY

(4, 5, 12, 14)

PURPOSE:

To calculate the mechanical advantage and the efficiency of an inclined plane.

MATERIALS:

inclined plane
support stand
cart or roller skate or object that can be dragged up the plane
spring scale calibrated in newtons
meter stick

PROCEDURE:

(1) Set up the inclined plane as shown.

(2) Measure and record the length and the height of the plane.

(3) Weigh the cart or object and record. This is the resistance force.

(4) Gently pull the cart or drag the object up the plane, keeping the spring scale at the same slant as the plane. Read the spring scale and record. This is the effort force.

(5) Calculate the Ideal Mechanical Advantage (IMA) of the plane.

$$\text{IMA} = \frac{\text{length of plane}}{\text{height of plane}}$$

(6) Calculate the Actual Mechanical Advantage (AMA) of the plane.

$$\text{AMA} = \frac{\text{resistance force}}{\text{effort force}}$$

(7) Compare the IMA to the AMA. How are they different?

(8) Calculate the work output by multiplying the resistance force by the height of the plane.

Work output = resistance force × height of plane

(9) Calculate the work input by multiplying the effort force by the length of the plane.

Work input = effort force × length of plane

(10) Compare the work input with the work output. How are they different? Why?

(11) Calculate the efficiency of the inclined plane.

$$\text{Efficiency} = \frac{\text{work output}}{\text{work input}} \times 100$$

RESULTS:

The effort force is less than the resistance force. The ideal mechanical advantage is greater than the actual mechanical advantage. The work input is greater than the work output, mainly because of friction. The efficiency is less than 100 percent. If an object is dragged, the difference between the IMA and AMA will be greater, and the efficiency will be less, due to the greater friction involved.

G-21. COMPLEX MACHINES
(1, 2, 14, 17)

PURPOSE:

To demonstrate the relationship between complex and simple machines.

PROCEDURE:

(1) Choose a machine with which you are familiar, such as a car engine, a lawn mower, an electric mixer, or a pencil sharpener.

(2) List each part in the machine you chose.

(3) State what kind of simple machine each part is.

RESULTS:

Complex machines are made up of many simple machines and are dependent upon the interaction of these simple machines. Some simple machines are employed more than others in everyday use.

G-22. SOUND: VIBRATION OF MATTER
(1, 2, 4, 14)

PURPOSE:

To demonstrate how sound is produced.

MATERIALS:

tuning fork
aluminum foil ball suspended from a string
beaker of water

PROCEDURE:

(1) Tap the tuning fork. Look at it and listen carefully. Record your observations.

(2) Tap the tuning fork and let it touch the foil ball suspended from the string. Record your observations.

(3) Tap the tuning fork and carefully let one prong touch the surface of the water in the beaker. Record your observations.

(4) Tap the tuning fork. Carefully, but firmly, hold the *handle* of the fork against the side of the beaker. Record your observations.

(5) Tap the tuning fork and hold the *handle* firmly against your chin. Record your observations.

(6) What conclusion can you draw based on your observations?

RESULTS:

When the tuning fork is tapped, the prongs vibrate and a sound is produced. The vibration of the prongs causes the foil ball to bounce around and the water in the beaker to splash. The vibration of the prongs can be felt against the chin.

G-23. LONGITUDINAL AND TRANSVERSE WAVES
(1, 2, 4, 14)

PURPOSE:

To demonstrate the difference between longitudinal and transverse waves.

MATERIALS:

coil spring (a "slinky" or coiled extension cord)
supports (See Diagram A.)

DIAGRAM A

PROCEDURE:

(1) Tie one end of the coil spring to a doorknob.

(2) Hold the other end in your hand and move your hand up and down. The energy you have given the coil travels along the coil as a transverse wave.

(3) Observe the transverse waves you produce. In what direction do the waves move? In what direction does the spring move? Record your observations either in words or with a diagram.

(4) Suspend the coil spring between two upright supports (or from a movie screen) so that it is slightly extended. (See Diagram A.). Tie strings at regular intervals along the coil to give additional support.

(5) Pinch together or pull a few coils at one end of the spring and release. The energy you have given the coil travels along the coil as a longitudinal wave.

(6) Observe the longitudinal waves you produce. In what direction do the waves move? In what direction do the coils vibrate? Record your observations either in words or with a diagram.

(7) Compare the two waves you produced. In each, how does the direction of vibration compare with the direction of wave motion?

RESULTS:

The transverse waves have an up and down motion. The longitudinal waves have a back-and-forth motion.

DIAGRAM B

Transverse Wave

Longitudinal Wave

G-24. RELATIONSHIP OF FREQUENCY TO PITCH

(1, 2, 14, 17)

PURPOSE:

To observe the relationship between frequency and pitch.

MATERIALS:

an open box
rubber band

PROCEDURE:

(1) Place the rubber band around the open box.

(2) Lightly strum the rubber band.

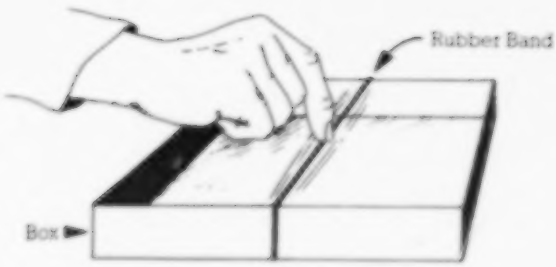
(3) Observe the vibrations. Note how fast they are and note the sound produced.

(4) Tighten the rubber band slightly by pulling one end.

(5) Observe the frequency and the sound of the vibrations again.

(6) Repeat, tightening the rubber band a little bit more.

(7) What conclusion can you draw?



RESULTS:

As the rubber band is tightened, it vibrates faster (its frequency increases). As frequency increases, the pitch becomes higher.

G-25. LOUDNESS
(1, 2, 4, 14, 17)

PURPOSE:

To observe the relationship between the loudness of a sound and the amount of energy put into the sound wave.

MATERIALS:

test tube half filled with water

PROCEDURE:

(1) Blow gently across the top of the test tube. Find the right angle at which to hold it to produce a "musical" sound. Record your observations.

(2) Repeat, blowing harder. Record your observations.

(3) Repeat a third time, blowing harder still. Record your observations.

(4) What conclusion can you draw?

RESULTS:

More energy is applied to the air in the test tube as the person blows harder. As more energy is applied, the sound will be louder.

G-26. REFLECTION AND THE SPEED OF SOUND
(1, 4, 5, 12)

PURPOSE:

To use the reflection of sound to measure its speed.

MATERIALS:

two blocks of wood
metric tape measure (or a meter stick)

PROCEDURE:

(1) Go outside and stand 40-50 m from a side of the school building that faces an open area.

(2) Clap the two blocks of wood together. You should hear the original sound and an echo.

(3) Slowly move toward the building, clapping the blocks of wood from time to time, until you can no longer hear the echo. Mark this spot.

(4) Measure the distance in meters from this spot to the building.

(5) Determine the total distance in meters from this spot to the building and back again.

(6) Find the speed of sound by dividing the total distance by the time it took for the sound to travel that far. The time is 0.10 second, which, on average, is the

length of time that must occur between sounds before we can distinguish them as separate sounds.

(7) From your measurements, what is the speed (in meters per second) of sound?

RESULTS:

The speed of sound is approximately 340m/sec. When sounds occur less than 0.10 second apart, humans can no longer perceive them as separate sounds. In 0.10 second, sound travels a distance of 34 m. The distance from the building that will give this total distance is 17 m. Individual students' abilities to distinguish between sounds will vary from 0.10 second and thus different students will mark different distances from the building at which the echo can no longer be heard (generally from 12 to 22 meters). The calculated speed of sound will therefore vary.

G-27. RESONANCE
(1, 2, 4, 14)

PURPOSE:

To observe resonance.

MATERIALS:

two tuning forks of the same frequency
another tuning fork of a different frequency
resonance boxes (if available)

PROCEDURE:

(1) Pick up the two tuning forks of the same frequency.

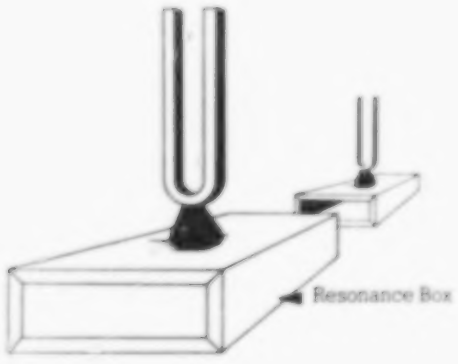
(2) Strike one fork, then place both forks several feet apart on a table.

(3) After several seconds, stop the vibration of the first tuning fork. Is the second fork vibrating? (If resonance boxes are attached to the two tuning forks, the results are more obvious. Place the boxes so that the open ends face each other.)

(4) Repeat, using one of the original tuning forks and another one of a different frequency. What happens?

RESULTS:

The vibration of one tuning fork causes a second tuning fork of the same frequency to vibrate. A second tuning fork of a different frequency does not vibrate.



G-28. TRANSMISSION OF SOUND WAVES THROUGH A MEDIUM

(Teacher Demonstration) (1, 2, 14, 17)

PURPOSE:

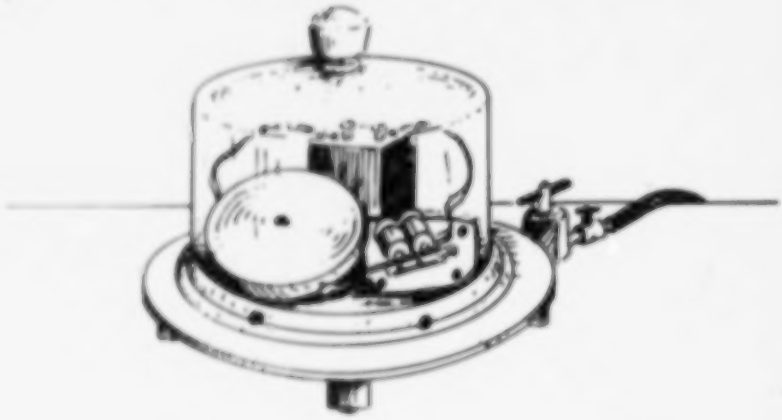
To demonstrate that sound requires a medium through which to travel.

MATERIALS:

bell jar
pump plate
bell in series with a switch and dry cell, or a music box, or a wind-up musical toy
wires
rubber stopper
vacuum pump

PROCEDURE:

(1) Set up the bell circuit and bell jar as shown in the diagram. Close the switch.
(2) Place the opening of the bell jar on top of the pump plate. Connect the pump plate to the pump.
(3) Note the loudness of the sound caused by the bell.
(4) Turn on the pump. Note what happens to the loudness of the bell as air is removed from the bell jar. Why does this happen?



RESULTS:

As the air is removed from the bell jar, the loudness of the sound decreases. Ultimately, no sound can be detected because there is no longer enough air in the jar for sound to be able to travel through it.

G-29. MUSIC AND LIVING ORGANISMS

(1, 2, 8, 9, 10, 16)

PURPOSE:

To demonstrate that music affects living things.

Part A

MATERIALS:

source of hard-rock music
source of classical music
two groups of plants of the same species, size, age, etc.

PROCEDURE:

(1) Place one group of plants in a controlled environment with hard-rock music and the other in a controlled environment with classical music.
(2) Decide on a series of tests that will measure the

health, growth, or condition of each group of plants.

(3) Determine if there are different effects on the plants from the two kinds of music. What are the effects? How long does it take for the effects to become obvious?

Part B

MATERIALS:

oral thermometer
watch or clock with a second hand

(Caution: An oral thermometer should be properly sterilized and used only under the supervision of the school nurse.)

PROCEDURE:

(1) Measure pulse rate, body temperature, reaction time, or some other body function of a group of people exposed to different kinds of music. (**Caution:** Make sure that students are not exposed to hazardous conditions, especially music that is too loud, while these investigations are being carried out.)

(2) Record your observations. Do the different kinds of music affect body functions differently?

RESULTS:

Since students will be helping to devise their own investigations, results will vary.

G-30. NOISE AND HEALTH

(14)

PURPOSE:

To become aware of the effects of noise pollution.

MATERIALS:

the article, "Airport Noise Linked with Heart Disease" (Appendix C-2)
the article, "Noise Pollution" (Appendix C-3)

PROCEDURE:

After reading both articles, place a check next to each of the statements with which you agree. When you have reacted to all of the statements, compare your responses with those of your classmates. Where you have differences, discuss the reasons for those differences. Try to understand the positions taken by those who differ with you. Where you have the same responses, discuss them to see if your agreements are based on similar or different reasons.

_____ 1. Noise is correlated with suicide and heart disease.

_____ 2. People who live near an airport are more likely to have heart or blood vessel disease.

_____ 3. Airport noises are often above 100 decibels.

_____ 4. Noise has more of an effect on the health of older people.

_____ 5. Murder, suicide, and auto accidents are more prevalent in high noise areas.

_____ 6. Noise can result in permanent damage to hearing.

_____ 7. It is a good idea to have a law such as the Noise Control Act to protect people from noise pollution.

_____ 8. The lowest safe decibel level is 85 dB.

_____ 9. A law reducing the maximum decibel level to 85 dB in the workplace is needed.

_____ 10. I shouldn't play my stereo or radio too loudly.

_____ 11. If my parents operate a riding lawn mower or chain saw, they should wear ear protection.

RESULTS:

The questions are intended to encourage students to react critically to the articles. There are no right or wrong answers: a student's response depends on whether the student accepts the information given in the articles or not.

G-31. NOISE IN THE WORK PLACE

(8, 14)

PURPOSE:

To investigate how noise is controlled in the work place.

MATERIALS:

decibel meter (optional)

PROCEDURE:

(1) Interview several people who have different occupations and find out if and how they are affected by noise where they work. Record the results of your interviews.

(2) Interview several different employers in the area and ask what precautions they take to protect their workers from the adverse effects of noise. Record the results of your interviews.

(3) (Optional) Record the noise level in a quiet classroom, in the cafeteria during lunch, in gym during a physical education class, and outside during a physical education class. Ask your teachers and other students how they are affected by the higher levels. Were there differences in how other students and how your teachers were affected? Were any of the noise levels dangerous?

(4) Find out from local officials or from a library what the Occupational Safety Health Act (OSHA) regulations for noise are. Report your findings either in a written summary or graphically.

RESULTS:

It is likely that both employees and employers consider noise a serious problem in the work place. OSHA establishes regulations for noise control for certain kinds of employers.

G-32. ELECTROMAGNETIC SPECTRUM

(17, 18)

PURPOSE:

To investigate the relationship among the waves that make up the electromagnetic spectrum.

MATERIALS:

paper
pencil
ruler

PROCEDURE:

(1) Use your textbook or a model provided by your teacher to make a chart of the electromagnetic spectrum.

(2) Answer the following questions.

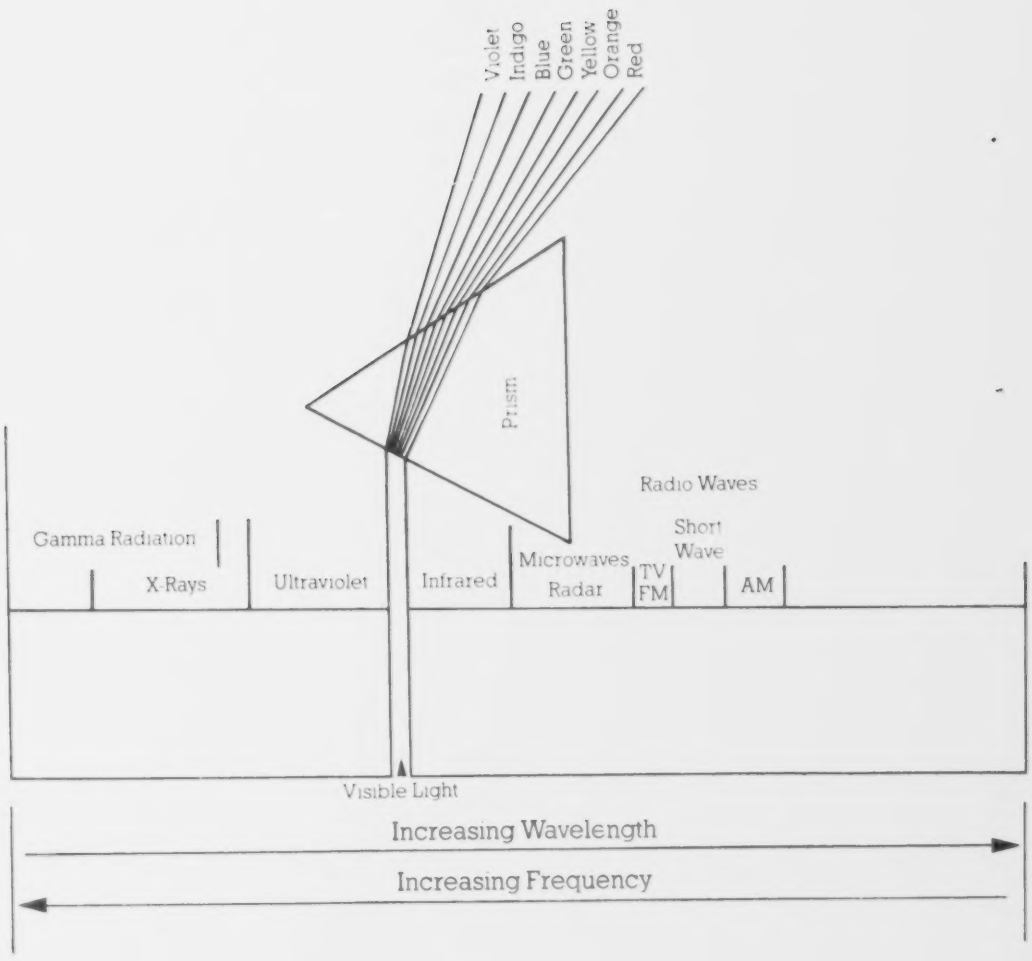
(a) At which end of the spectrum are the wavelengths the shortest? The longest?

(b) At which end of the spectrum are the frequencies the highest? The lowest?

(c) What is the relationship between frequency and wavelength? How would you graph this relationship?

(d) In general, what kinds of waves have short wavelengths and high frequencies? Long wavelengths and low frequencies?

(e) About what proportion of the spectrum contains the visible light wavelengths?



RESULTS:

The shorter wavelengths of the electromagnetic spectrum have higher frequencies (and are the most dangerous). Visible light, the only part of the spectrum which we are consciously aware of, is a very small part of the electromagnetic spectrum.

G-33. THE VISIBLE LIGHT SPECTRUM

(Teacher Demonstration) (1, 2)

PURPOSE:

To demonstrate the composition of white light.

MATERIALS:

black paper
flashlight or projector
glass prism
white cardboard or a screen
colored pencils

PROCEDURE:

(1) Cut a narrow slit in a piece of black paper.

(2) Cover the lens of the flashlight or projector with the paper.

(3) Place the glass prism on a stand near a screen or white cardboard. Darken the room and direct the beam of light from the flashlight toward the prism.

(4) Turn the prism slowly until a band of colors appears on the screen.

(5) Note the arrangement of the colors. Make a diagram of the spectrum, using colored pencils.

G-34. LIGHT TRAVELS IN STRAIGHT LINES

(Teacher Demonstration) (1, 2)

PURPOSE:

To demonstrate that light travels in straight lines.

MATERIALS:

projector or flashlight
chalk dust

(Caution: Before doing this activity, make sure no students are allergic to chalk dust.)

PROCEDURE:

(1) Place the light source so that its beam can shine across the length of the room.

(2) Darken the room and turn on the light source.

(3) Ask a student to clap two erasers together in the beam of light.

(4) Ask students to state their observations.

(5) (Optional) Make a small hole or slit in a piece of cardboard and hold it in the beam of light. Ask students to state their observations.

RESULTS:

The beam of light travels in a straight path through the chalk dust.

G-35. INTENSITY AND ILLUMINATION

(1, 2, 14, 17)

PURPOSE:

To demonstrate the relationship between the illumination of a surface and the distance between the light source and the surface.

MATERIALS:

projector or other light source
cardboard
screen
metric ruler or meter stick
light meter (optional)

PROCEDURE:

(1) Make a pinhole in the cardboard. Place the cardboard in front of the lens of the light source.

(2) Place a screen at a measured distance from the cardboard.

(3) Observe the brightness (illumination) and the size of the spot on the screen.

(4) If a light meter is available, record its reading.

(5) Double, then triple the distance of the screen from the source. Observe what happens each time.

(6) Does the size of the spot change as the distance from the source changes? If so, how? Does the brightness change? If so, how?

(7) What conclusions can you draw about the relationship between illumination of a surface and the distance of the surface from the light source? How would you graph this relationship?

RESULTS:

The size of the spot of light on the screen increases and the illumination decreases as the distance from the source increases.

G-36. REFLECTION OF LIGHT FROM A PLANE MIRROR

(1, 2, 4,14,17)

PURPOSE:

To demonstrate how light is reflected from a mirror.

MATERIALS:

flashlight
plane mirror
piece of black cardboard
piece of white cardboard
chalk dust

(**Caution:** Before doing this activity, make sure no students are allergic to chalk dust.)

PROCEDURE:

(1) Make a hole in the black cardboard and place it over the lens of the flashlight.

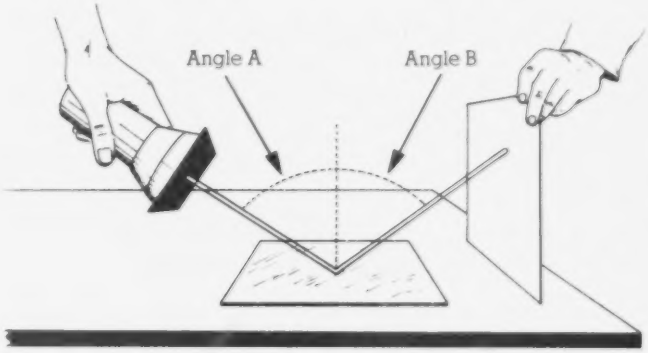
(2) Place the mirror on a table, darken the room, and direct the narrow beam of light onto the mirror. Make the beam of light visible by shaking a little chalk dust into it.

(3) Place a piece of cardboard perpendicular to the tabletop so that the beam reflecting off the mirror will strike it.

(4) Using a protractor, measure angles A and B shown in the diagram.

(5) Change the angle of the flashlight and again measure angles A and B. Repeat with several other angles of the flashlight.

(6) What is the relationship between angles A and B in every case? How would you graph this relationship?



RESULTS:

Angle A equals angle B (the angle of reflection equals the angle of incidence) in every case.

G-37. IMAGES FORMED BY MIRRORS

(1, 2, 4, 6)

PURPOSE:

To observe the kind of image formed by a plane mirror.

MATERIALS:

plane mirror
clock
cardboard
transparent paper with writing on it

PROCEDURE:

(1) Place the clock in front of, and facing, the plane mirror.

(2) Observe the image of the clock face in the mirror.

(3) Describe the image of the clock.

(4) Place the cardboard as far behind the mirror as the clock is in front of it. Is there an image on the cardboard?

(5) Place the transparent paper in front of the mirror with the writing facing you.

(6) Describe the image of the writing.

RESULTS:

The image of the clock is right side up and the numbers are reversed (because the clock was turned around to face the mirror). The image of the writing is right side up and not reversed (since it wasn't turned around). No image falls on the cardboard because the image only "appears" to be as far behind the mirror as the clock is in front of it. (This kind of image is known as a virtual image.)

G-38. REFRACTION

(1, 2, 4, 6)

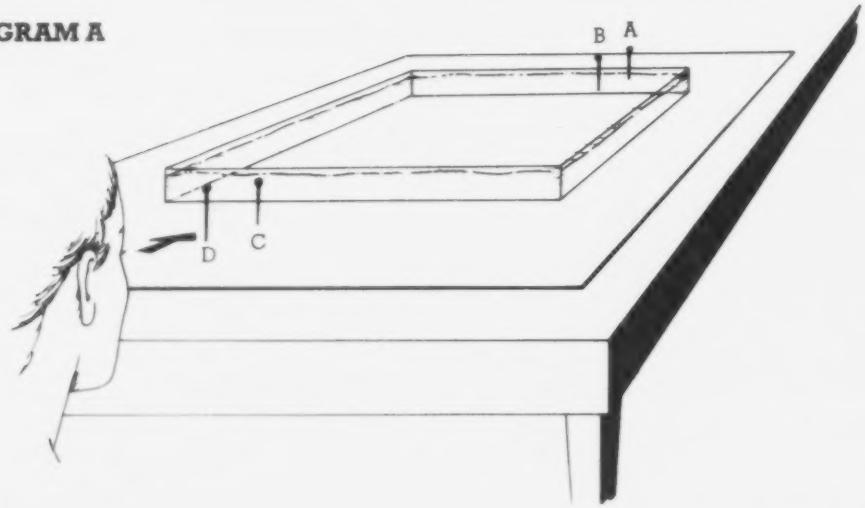
PURPOSE:

To observe the refraction of light.

MATERIALS:

clear rectangular dish
piece of cardboard larger than the dish

DIAGRAM A



four pins
water

PROCEDURE:

(1) Fill the dish almost to the top with water and place it on a piece of cardboard on a table.

(2) With a pencil, draw the outline of the dish on the cardboard.

(3) Place pins A and B in the cardboard as shown in Diagram A. A line connecting the points should strike the dish at an angle.

(4) Go to the opposite side of the dish from pins A and B and place yourself so that your eyes are level with the side of the dish. Sight along pins A and B. Place two additional pins (C and D) on your side of the dish so that all four pins appear to be on the same line. (See Diagram A.)

(5) Remove the dish.

(6) Draw lines AB and CD just to the outline of the dish.

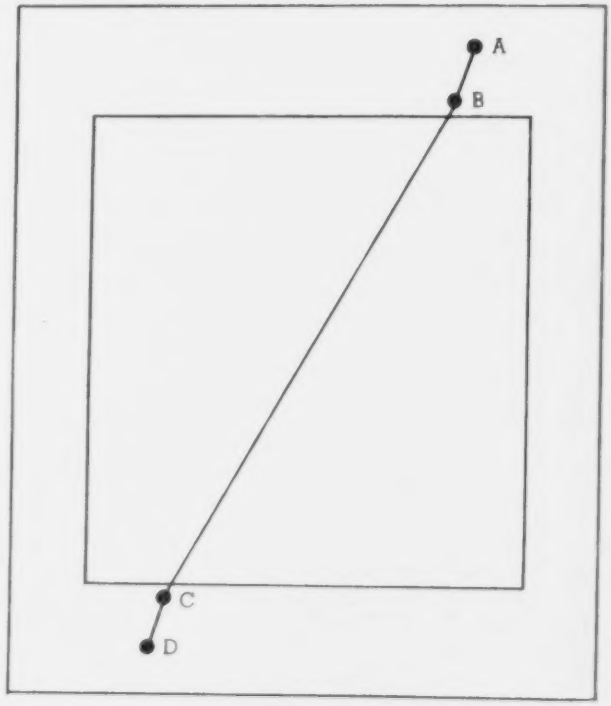
(7) Draw BC.

(8) Is line ABCD a straight line? If not, where does it bend?

RESULTS:

Line ABCD bends twice. (See Diagram B.) As a light ray passes from less dense air into more dense water, its speed is reduced and the ray is bent toward the normal. As a light ray passes from more dense water into less dense air, it is bent away from the normal.

DIAGRAM B



G-39. LENSES

(1, 2)

PURPOSE:

To demonstrate the differences between concave and convex lenses.

MATERIALS:

concave lens
convex lens

PROCEDURE:

(1) Look at many different objects (print in your textbooks, pencils, your fingers) through both types of lenses and record your observations.

(2) Put the two types of lenses together and record your observations.

RESULTS:

A convex lens makes objects look bigger and a concave lens makes objects look smaller. When the lenses are placed together, there is less apparent change in size.

G-40. IMAGES FORMED BY LENSES

(1, 2, 4, 14)

PURPOSE:

To use a lens to produce a real image.

MATERIALS:

piece of cardboard with white paper attached to the front
small magnifying glass (convex lens)

PROCEDURE:

(1) Stand with your back to a window. Hold the cardboard upright in front of you.

(2) Hold the lens in front of the cardboard.

(3) Slowly move the lens away from the cardboard until you see an image of the window on the cardboard. Adjust the lens so that the image is clear.

(4) Study the image carefully. Is the image larger or smaller than the window itself? Is the image right side up or upside down? How does this image compare to one formed by a plane mirror as in Activity G-37?

(5) Record your observations.

(6) What are your conclusions?

(7) Draw a diagram that represents what happens to the light rays as they pass through the lens and are focused on the cardboard.

RESULTS:

The image of the window is smaller than the window itself and is upside down. When light waves pass through a convex lens they are refracted to form a smaller image.

G-41. COLORS AND MOODS

(14)

PURPOSE:

To find out how color may affect our moods and reactions.

MATERIALS:

the article, "How Color Affects Your Moods and Health" (Appendix C-4)

PROCEDURE:

After reading the article, place a check next to each of the statements with which you can agree. When you have reacted to all of the statements, compare your responses with those of your classmates. Where you have differences, discuss the reasons for those differences. Try to understand the positions taken by those who differ with you. Where you have the same responses, discuss them to see if your agreements are based on similar or different reasons.

_____1. Color can control a violent person.

_____2. Our eyes and brain can sometimes make us see "true" colors even when the color of the light shining on objects changes.

_____3. Colors and patterns can cause emotional responses in people.

_____4. Colors and patterns can make people buy certain products.

_____5. Colors can make things appear bigger or smaller than they really are.

_____6. Pink can make you weak.

_____7. Red can make you feel warmer.

_____8. Color can cause biological changes in people.

RESULTS:

The questions are intended to encourage students to react critically to the article. There are no right or wrong answers: a student's response depends on whether the student accepts the information given in the article or not.

G-42. COLOR

(Teacher Demonstration) (1, 2, 14, 17)

PURPOSE:

To demonstrate how the color of objects changes in different light sources.

MATERIALS:

projector or other light source
colored filters (cellophanes)
a "black" light
various sources of "white" light (warm and cool "white" incandescent and fluorescent bulbs, etc.)
various objects of different textures and colors (The United States flag in the room is one good choice.)
(**Caution:** Do not look directly into ultraviolet light sources.)

PROCEDURE:

(1) Darken the room and turn on the projector or other source of light.

(2) Cover the light source with a colored filter and direct the colored light onto different objects.

(3) Ask the class to name the color of each object.

(4) Repeat using different colored filters.

(5) View the same objects in "black" light and in "white" light from different sources.

(6) In what ways does the color of an object depend on the color of the light source? On the texture of the object?

(7) Did objects in different sources of "white" light look different? How?

RESULTS:

The same object will appear to be different colors or tones in lights of different colors. White light from different sources will cause objects to have different tones.

G-43. ILLUSIONS

(1, 2, 5, 14)

PURPOSE:

To observe common optical illusions.

MATERIALS:

metric ruler

DIAGRAM A

DIAGRAM B

PROCEDURE:

(1) In Diagram A, which line appears shorter? In Diagram B, is the hat as wide as it is high? Measure the lengths of the lines in Diagram A and the height and width of the hat in Diagram B. Were your guesses right?

(2) Compare Diagrams C and D. Is circle 1 smaller than circle 2? Measure them to check your answer.

(3) In Diagram E, which of the two ladders (1 or 2) is longer? Measure them to check your answer.

(4) Bring to class other examples of optical illusions.

DIAGRAM C

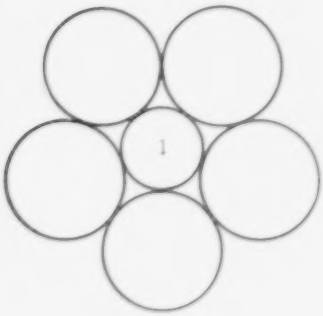


DIAGRAM D

DIAGRAM E

G-44. MORE ILLUSIONS

(1, 2, 4, 14)

PURPOSE:

To demonstrate illusions created by refraction.

MATERIALS:

an opaque cup
a clear glass filled with water
penny
pencil
water

PROCEDURE:

(1) Place the penny in the cup and hold it in place with the eraser end of the pencil.

(2) Position your head so the cup's rim barely hides the penny from view.

(3) Without changing your position, carefully pour water into the cup. Be careful not to disturb the penny. Observe what happens.

(4) Place the pencil in the glass filled with water. What do you observe?

RESULTS:

The penny appears to rise in the cup. It can be clearly seen. The pencil appears to be broken. Both illusions are caused by the refraction of light waves as they pass from one medium to another.

G-45. LIGHT AND ADVERTISING
(1, 2)

PURPOSE:

To demonstrate how advertisers and designers can make us see things the way they want us to see them.

MATERIALS:

magazines and catalogs
food wrappers and containers

PROCEDURE:

(1) Collect pictures from magazines and/or catalogs which demonstrate how visual effects are used to make us want to buy certain products.

(2) Watch television commercials carefully to see if the surroundings of the objects have an effect on how they look.

(3) Bring to class a food wrapper or container on which the use of light and color added to its appeal.

(4) Observe produce and meat displays in supermarkets to see if different types of light or other visual effects are used to make the products seem more appealing.

G-46. MODELS FOR HEAT
(18, 20)

PURPOSE:

To find out more about two models that explain heat energy.

MATERIALS:

the article, "Heat: An Atomic Dance" (Appendix C-5)

PROCEDURE:

After reading the article, answer the following questions. Base your answers on the information given in the article.

(1) What was the "caloric" model for heat?

(2) Who first suggested that this model might be incorrect?

(3) What model do we use today to explain heat energy? Describe the model.

(4) Why do metals conduct heat quickly?

(5) What two substances are good insulators?

(6) How does a thermos bottle work?

RESULTS:

Students should answer the questions from the information given in the article. (Students are being asked to accept the information in this article as an explanation of heat.)

G-47. WHAT HAPPENS TO GASES WHEN THEY ARE HEATED?

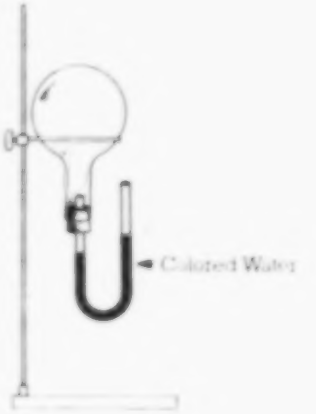
(1, 2, 4, 9, 14)

PURPOSE:

To observe what happens to gases when they are heated.

MATERIALS:

flask or test tube
one-holed rubber stopper
U-tube
colored water
wax pencil
palm glass (optional)



PROCEDURE:

(1) Set up the equipment as shown in the diagram. Mark the level of the water in the open end of the U-tube.

(2) Place your hands on the flask for 2 minutes.

(3) What do you observe? Why does this happen?

(4) Take your hand away. What do you observe? Why does this happen?

(5) Can you cause more movement than the other students can? How? Try your idea.

(6) Ask your teacher to demonstrate a palm glass for you.

RESULTS:

The colored water will move toward the open end of the U-tube. The air in the flask is warmed by the hands, expands, and pushes the water toward the open end of the U-tube. When the hands are removed, the air in the flask cools and contracts, and the water returns to its original level. More movement can be caused by rubbing the hands together before placing them on the flask.

G-48. WHAT HAPPENS TO LIQUIDS WHEN THEY ARE HEATED?

(1, 2, 4, 14)

PURPOSE:

To observe what happens to liquids when they are heated.

MATERIALS:

flask or test tube
one-holed rubber stopper
glass tube
colored water
beaker or pan of hot water
wax pencil

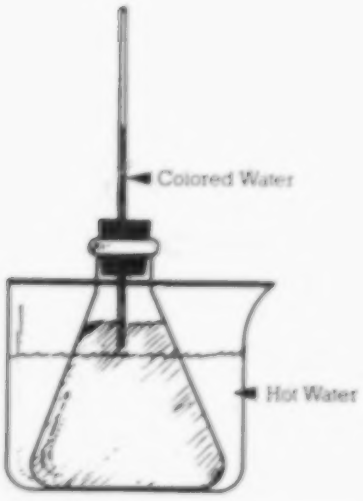
PROCEDURE:

(1) Set up the equipment as shown in the diagram. Mark the height of the colored water in the tube.

(2) Place the test tube or flask in a beaker or pan of hot water.

(3) What do you observe? Why does this happen?

(4) What measuring instrument is based on the principle demonstrated in this activity?



RESULTS:

The colored water will rise in the tube. The water in the flask is warmed and expands up the tube. Thermometers are based on this principle and they work because the liquid in them expands more than the glass tube that surrounds the liquid.

G-49. WHAT HAPPENS TO SOLIDS WHEN THEY ARE HEATED?

(1, 2, 4, 14)

PURPOSE:

To observe what happens to solids when they are heated.

MATERIALS:

ball-and-ring expansion device
Bunsen burner or other source of heat
safety glasses

PROCEDURE:

(1) Slide the ball through the metal ring.

(2) Heat just the ball and try to slide it through the ring. (**Caution:** Always wear safety glasses when using a Bunsen burner.)

(3) What do you observe? Why does this happen?

(4) Heat the ring and ball together. Now try to slide the ball through the ring.

(5) What do you observe? Why does this happen?

RESULTS:

When just the ball is heated, it expands and becomes too large to fit through the ring. If the ring is also heated, it also expands, and the ball can again fit through the ring.

G-50. PHASES OF MATTER

(Teacher Demonstration) (18, 19,20)

PURPOSE:

To use a model to demonstrate and explain the phases of matter.

MATERIALS:

overhead projector
marbles
three clear containers of unequal size (The largest container should be much larger than the other two.)

PROCEDURE:

(1) Put as many marbles into the smallest container as can be packed into a single layer. Put an equal number of marbles into each of the remaining containers.

(2) Set each container on the stage of the overhead projector. Gently jiggle each container so that the marbles move.

(3) In which container are the marbles the closest together? The farthest apart (on the average)?

(4) In which container do the marbles move around the least? The most?

(5) If the marbles represent the particles in a material, which container of marbles represents a solid? A liquid? A gas? Why?

RESULTS:

The smallest container represents a solid, the next largest a liquid, and the largest a gas. The "marble" model illustrates the particle model for matter.

G-51. CHANGE IN PHASE

(5, 6, 9, 12, 13, 14, 15, 16, 21, 23)

PURPOSE:

To demonstrate what happens to the temperature of a material as it changes phase.

MATERIALS:

hot plate or Bunsen burner
pyrex beaker
crushed ice
Celsius thermometer
timing device
stirring rod
safety glasses

PROCEDURE:

(1) Fill a beaker with crushed ice and place the thermometer in the center of the ice.

(2) Hypothesize what you think will happen to the temperature of this material as it is heated over a period of time.

(3) Put the beaker on a hot plate and slowly heat it. (**Caution:** Wear safety glasses.) Stir the water continuously.

(4) Record the temperature in the beaker at 30-second intervals. Continue until half the water has boiled away. Circle the reading just before all the ice has melted and the reading when boiling just begins.

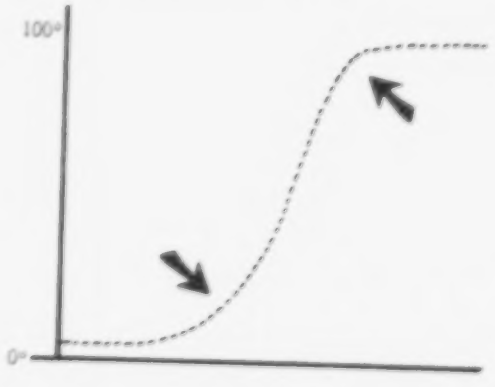
(5) Graph your data with temperature on the y axis and time on the x axis. Use an arrow to indicate the points that show the readings circled in (4).

(6) Was your hypothesis in (2) correct? Why or why not?

(7) Try to add to the model demonstrated in Activity G-50 so that you can also use it to explain what happened in this activity.

RESULTS:

The graph will look similar to the one shown below. Although heat is added at a uniform rate, the temperature of the material will not rise uniformly. The temperature remains constant for a time near 0°C because a phase change occurs. The heat energy added during this time is used to break the forces holding the particles in the solid state. When all the ice has turned to water, the temperature begins to rise again as the heat energy being added increases the kinetic energy of the particles of the liquid. The temperature will level off again near 100°C, while the forces holding the particles in the liquid state are broken. If all the water turned to steam, the temperature of the gas would rise as the heat energy added increased the kinetic energy of the particles of the gas.



G-52. IS THE BODY A GOOD THERMOMETER?

(1, 2, 4, 5, 14)

PURPOSE:

To investigate temperature and to determine if the body is a good thermometer.

MATERIALS:

three 500 ml beakers
three thermometers
ice

PROCEDURE:

(1) Half fill one beaker with water at room temperature, a second with ice water, and the third beaker with water between 35° and 40° C. (**Caution:** Make sure the hot water will not scald the student.)

(2) Suspend a thermometer in each beaker and record the temperatures after 2 minutes. Remove the thermometers.

(3) Place one hand in the hot water and the other hand in the ice water for 2 minutes.

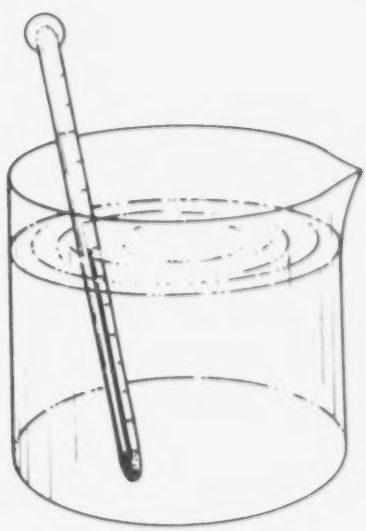
(4) Remove your hands and place them in the water at room temperature. Does the water at room temperature seem hot or cold?

(5) In which direction do you think heat is flowing with respect to each hand?

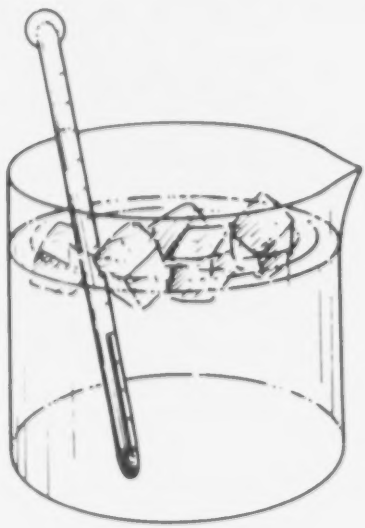
(6) Is the body a good thermometer? Why or why not?

RESULTS:

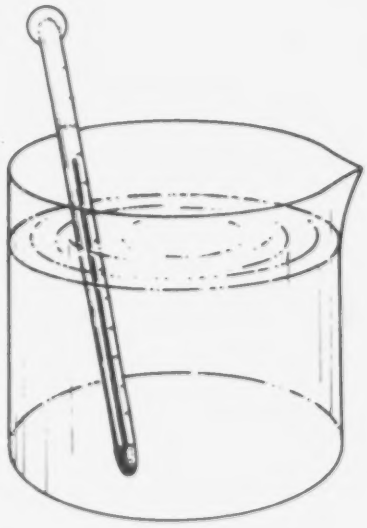
Temperature, when observed without the use of a thermometer, can be perceived only in comparison to a material at a different temperature. The human body is not a good thermometer because it adapts to different temperatures.



Room Temperature Water



Ice Water



Warm Water

G-53. USING A THERMOMETER
(1, 2, 4, 5)

PURPOSE:

To practice reading a Celsius thermometer.

MATERIALS:

labelled beakers containing various substances (hot water, water at room temperature, cold water, ice water, warmed cooking oil, refrigerated cooking oil, etc.)
Celsius thermometer suspended in each beaker

PROCEDURE:

(1) Read and record the temperature of the material in each beaker. (This may require a signal for students to move from station to station.)

(2) Compare your readings with those of other students. Are there differences, especially over time? Why do these differences occur?

(3) Why shouldn't you remove the thermometer from the beaker when you read it? Why shouldn't you shake the thermometer?

RESULTS:

Students should improve their skill in reading thermometers. Some readings taken at the beginning of class will be different from those taken at the end of class. Initially, this is because each thermometer must come into thermal equilibrium with the material. (A thermometer reads only its own temperature.) Later, heat transfer occurring between the material and the surrounding air causes a difference.

G-54. MAKING YOUR OWN THERMOMETER
(1, 4, 5, 14)

PURPOSE:

To construct a thermometer using your own temperature scale.

MATERIALS:

ice
water
wax pencil
pyrex beaker
hot plate
unmarked thermometer tube
tongue depressor
rubber band
safety glasses

DIAGRAM A

PROCEDURE:

(1) Place a mixture of ice and water in a beaker. Suspend an unmarked thermometer tube in the mixture. When the liquid in the tube stops moving, mark the position of the top of the liquid with a wax pencil.

(2) Heat the water to boiling. When the liquid in the tube stops rising, mark the position of the top of the liquid. (**Caution:** Wear safety glasses.)

(3) Use a rubber band to attach the thermometer tube to the tongue depressor.

(4) Choose a temperature to give to the ice-water mixture mark and a temperature to give to the boiling water mark.

(5) Mark these temperatures on the tongue depressor. Divide the area between these points into equal units and number the units correctly.

(6) Compare your temperature scale to others in the class. How are they similar? How are they different?

DIAGRAM B

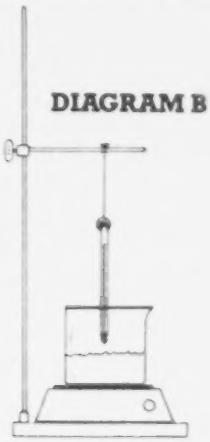


DIAGRAM C

(7) Measure the temperature of the air in the room with your thermometer. Do you get the same results as others in the room? Why or why not? If not, does this cause a problem in trying to report the temperature of the room?

RESULTS:

Each student should have a thermometer with a scale that is different from the others, just as the Celsius and Fahrenheit scales are different. Both the numbers assigned to the freezing and boiling points and the number of units between these points will vary among students. Students will not get the same readings for room temperature, which should point out the need for a common standard of measurement.

G-55. CALCULATING THE HEAT TRANSFERRED TO WATER

(1, 4, 5,12,14)

PURPOSE:

To calculate the amount of heat gained by water when it is heated on a hot plate.

MATERIALS:

Celsius thermometer
beaker of water
hot plate
graduated cylinder
clock
safety glasses

PROCEDURE:

(1) Place 100 ml of water in a beaker.

(2) Record the temperature of the water.

(3) Heat the beaker of water on the hot plate for 2 minutes. Record the temperature of the water at the end of the 2 minutes. (**Caution:** Wear safety glasses.)

(4) Determine the heat added to the water.

Heat (calories) = Mass of water (grams) × Temperature Change (°C)

(5) Let the water cool for 2 minutes. Record its temperature at the end of the 2 minutes.

(6) Determine the heat lost by the water by using the equation in (4).

(7) Heat the water for a longer (or shorter) period of time. Determine the heat added to it.

G-56. CONDUCTION
(1, 2, 4, 5)

PURPOSE:

To demonstrate the conduction of heat energy.

MATERIALS:

nail
candle firmly supported on a stand
clock or watch with a second hand

PROCEDURE:

(1) Light the candle.
(2) Hold the nail near its head and place the point in the flame. Hold the nail in the flame for about 15 seconds. (**Caution:** Do not let the nail get too hot or you may be burned.)
(3) Move the nail away from the candle flame and continue to hold it.
(4) What do you observe?

RESULTS:

Shortly after the nail is removed from the candle flame, its head will feel warm. The particles of the nail conduct heat energy along the nail. A time lag occurs between the time of heating and the time the nail head becomes warm. A conduction wheel can be used to demonstrate that conduction is not the same in all materials.

G-57. CONVECTION
(1, 2, 4, 14)

PURPOSE:

To demonstrate the transfer of heat energy by convection.

MATERIALS:

candle firmly supported on a stand
metric ruler

PROCEDURE:

(1) Light the candle.
(2) Hold your hand about 30 cm above the flame. Slowly lower your hand until you can feel heat. (**Caution:** Do not bring your hand too close to the flame or you may get burned.)
(3) How far from the flame is your hand?
(4) Why do you feel the heat if your hand is not in direct contact with the flame?
(5) Light a match and let it burn for a few seconds. Gently blow it out. While it is still smoking, hold it near the candle flame.
(6) Observe what happens to the smoke. Why did this happen?

RESULTS:

Heat will be felt between 15 and 20 cm from the flame. The candle flame heats the air above it. As this heated air expands, it becomes less dense, rises, and is replaced by cooler, more dense air. This air is in turn heated and also rises, setting up a convection current over the candle flame. The smoke from the match is drawn upward by the convection current.

G-58. RADIATION
(1, 2, 4, 14)

PURPOSE:

To demonstrate the transfer of heat energy by radiation.

MATERIALS:

candle firmly supported on a stand
metric ruler

PROCEDURE:

(1) Light the candle.
(2) Hold your hand about 30 cm to one side of the flame.
(3) Slowly move your hand toward the flame until you feel heat.
(4) How far from the flame is your hand? Is this distance closer to or farther from the flame than the distance you measured in Activity G-57?
(5) Why do you feel heat if your hand is not in direct contact with the flame? Why are the distances you measured in this activity and in Activity G-57 different?

RESULTS:

Heat will be felt between 5 and 10 cm from the flame. The heat felt in this case is transferred by radiation. Little convection occurs to the side of the flame.

G-59. MAGNETISM
(1, 2, 12, 14, 17)

PURPOSE:

To determine which substances are magnetic.

MATERIALS:

magnet
variety of objects such as a piece of iron, paper clips, an aluminum strip, wood, paper, coins, a copper wire
various minerals including magnetite

PROCEDURE:

(1) Bring a magnet near each object.
(2) Make a list of those objects attracted to the magnet.
(3) Do the objects attracted to the magnet have any common characteristics? Of what are they made?

RESULTS:

Not all substances are attracted to magnets. Those made of iron, cobalt, or nickel are attracted. Those made of other substances (like copper, aluminum, or wood) are not attracted.

G-60. TEMPORARY MAGNETS
(1, 4, 14)

PURPOSE:

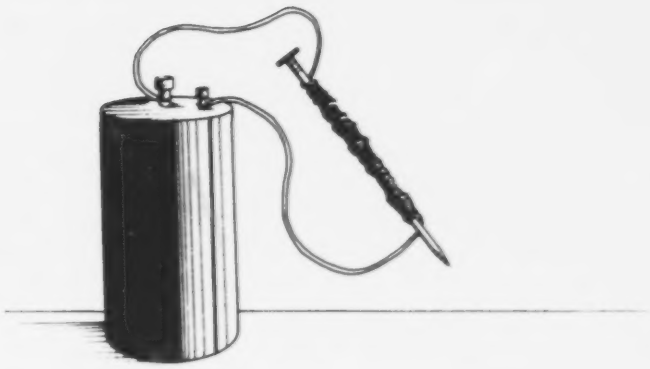
To make a temporary magnet.

MATERIALS:

iron nail
dry cell
50 cm of insulated bell wire
paper clips

PROCEDURE:

(1) Strip 3 cm of insulation from each end of the wire.
(2) Leaving 15 cm of wire at each end, wrap 100 turns of wire around the nail.
(3) Attach the free ends of the wire to the terminals of the dry cell as shown in the diagram.
(4) Touch the pointed end of the nail to some paper clips. What happens?
(5) Disconnect the dry cell and repeat (4). What happens?
(6) How could you make this temporary magnet stronger? (optional)



RESULTS:

The device constructed is an electromagnet. It picks up paper clips only when it is attached to the dry cell. An electromagnet is made stronger by increasing the number of turns of wire or by increasing the current (adding dry cells). A temporary magnet can also be made by contact.

G-61. PERMANENT MAGNETS

(2, 4, 14)

PURPOSE:

To make a permanent magnet.

MATERIALS:

steel knitting needle or steel nail
bar magnet
paper clips

PROCEDURE:

(1) Stroke the knitting needle in one direction with one end of the bar magnet.
(2) Can you pick up paper clips with the knitting needle?
(3) Wait a few minutes. Are the paper clips still attracted to the needle?

RESULTS:

The knitting needle is magnetized by the stroking. It will keep its magnetism for a longer period of time than the electromagnet (Activity G-60.) A permanent magnet can also be made in a solenoid.

G-62. STRENGTH OF A MAGNET

(1, 9, 14, 16)

PURPOSE:

To determine where a magnet is strongest.

MATERIALS:

bar magnet
paper clips

PROCEDURE:

(1) Predict where a magnet has its greatest strength.

(2) Test this prediction by seeing how long a paper clip chain you can make at various points along the magnet.

RESULTS:

The paper clip chains will be longest at either end (pole) of the magnet.

G-63. THE POLES OF A MAGNET

(1, 4, 14)

PURPOSE:

To observe how the two poles of a magnet are different.

MATERIALS:

compass
bar magnet

PROCEDURE:

(1) Lay the compass on the table and properly orient it. Slowly bring one end of the magnet near the north position on the compass. What happens to the needle of the compass?

(2) Bring the other end of the magnet near the north position on the compass. What happens?

(3) If the poles on the magnet are not already marked, label the north-seeking pole and the south-seeking pole.

RESULTS:

One end of the magnet attracts the point of the compass needle and the other end of the magnet repels the point. Magnets have unlike poles.

G-64. INTERACTION OF POLES

(8, 9, 10, 11, 14, 16)

PURPOSE:

To determine how the poles of two magnets affect each other.

Part A (Teacher Demonstration)

MATERIALS:

two magnets
overhead projector

PROCEDURE:

(1) Without identifying the magnets, place them on the overhead projector.
(2) Demonstrate attraction and repulsion without explaining.
(3) Ask students to identify the objects and the force that causes the results.

Part B

MATERIALS:

two bar magnets
string
a support from which to suspend one magnet

PROCEDURE:

(1) Hypothesize what would happen if the poles of two magnets were brought together.
(2) Design an investigation to test this hypothesis. (You may want one magnet to swing freely.)
(3) Carry out the investigation and record your results.

RESULTS:

Like poles (S-S or N-N) repel. Unlike poles (S-N or N- S) attract.

G-65. IRON FILINGS AND MAGNETIC FIELDS

(1, 2, 14)

PURPOSE:

To make visible the magnetic field of a magnet.

MATERIALS:

horseshoe magnet
bar magnet
iron filings
a piece of glass, clear rigid plastic, or paper

Note: If this activity is being done as a teacher demonstration, using an overhead projector will make the results easier to see. The magnet can be taped to the bottom of a Petri dish, the lid inverted and placed on top, and the iron filings sprinkled into the lid.

PROCEDURE:

(1) Lay the glass on the horseshoe magnet. Carefully sprinkle iron filings on the glass above the magnet. Tap the glass lightly.
(2) Make a sketch of the pattern of the iron filings.
(3) Repeat the procedure using a bar magnet.
(4) Why are iron filings used in the procedure?

RESULTS:

G-66. COMPASSES AND MAGNETIC FIELDS

(1, 2, 4, 14)

PURPOSE:

To demonstrate the magnetic field of a magnet.

MATERIALS:

bar magnet
compass
piece of paper

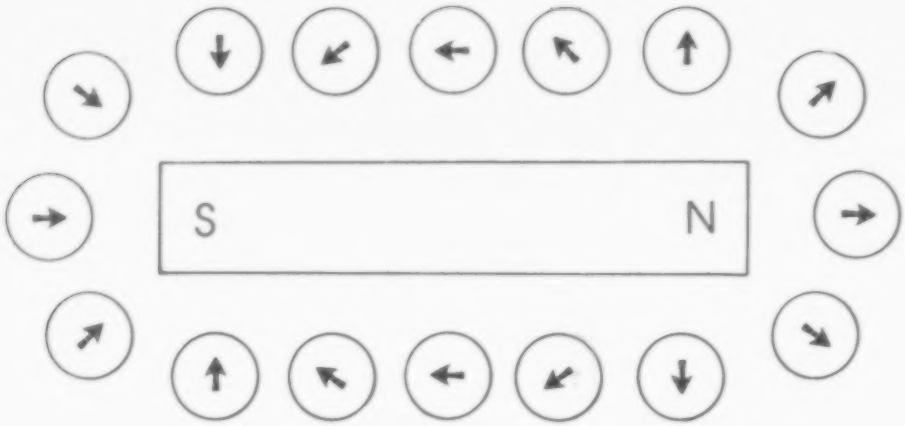
PROCEDURE:

(1) Lay the magnet in the middle of the paper.

(2) Place the compass about 4 cm from the magnet. Note the direction in which the compass needle points, remove the compass, and draw in the same spot on the paper the direction in which the needle pointed.

(3) Move the compass to other locations around the magnet, always keeping the compass about 4 cm from the magnet. Indicate with an arrow the direction of the needle at each location.

RESULTS:



G-67. TWO-DIMENSIONAL DISPLAY OF THE INTERACTION OF MAGNETIC FIELDS

(1, 2, 4, 14)

PURPOSE:

To demonstrate the two-dimensional interaction of two magnetic fields.

MATERIALS:

iron filings
two bar magnets
a piece of glass, clear rigid plastic, or paper

PROCEDURE:

(1) Place the two like poles of the magnets about 3 cm apart. Cover the magnets with the glass.

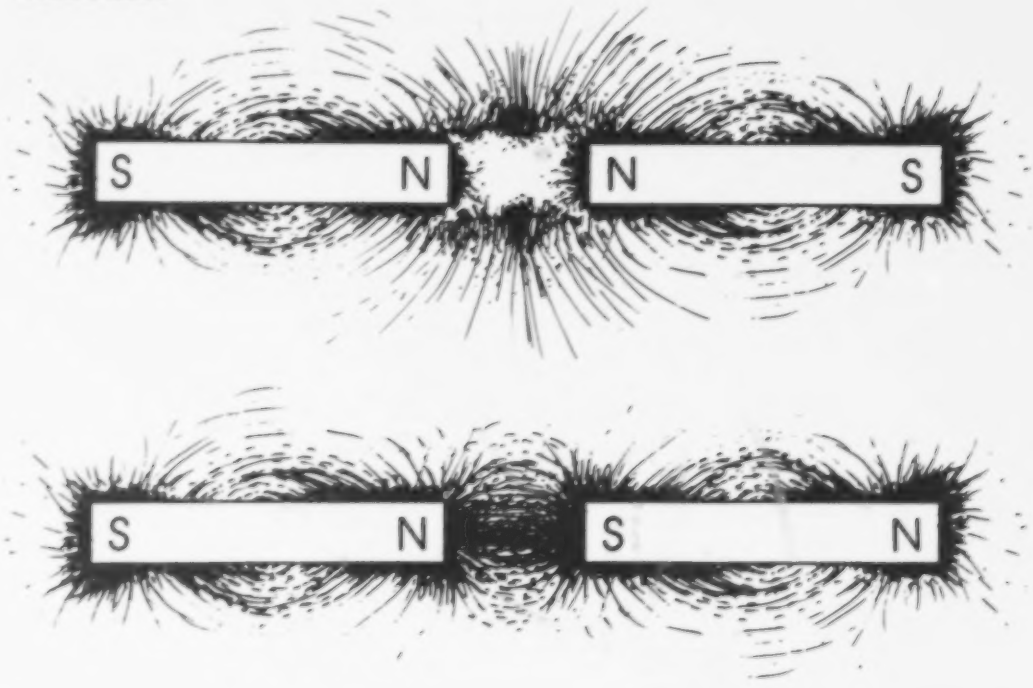
(2) Gently sprinkle iron filings on the glass. Tap the glass gently.

(3) Make a sketch showing the pattern of the iron filings.

(4) Repeat the procedure placing the two unlike poles of the magnets 3 cm apart.

(5) Why are the two sketches different?

RESULTS:



G-68. THREE-DIMENSIONAL DISPLAY OF THE INTERACTION OF MAGNETIC FIELDS

(1, 2, 4, 14)

PURPOSE:

To demonstrate the three-dimensional interaction of two magnetic fields.

MATERIALS:

a small clear plastic vial with a cap (a film case will work)

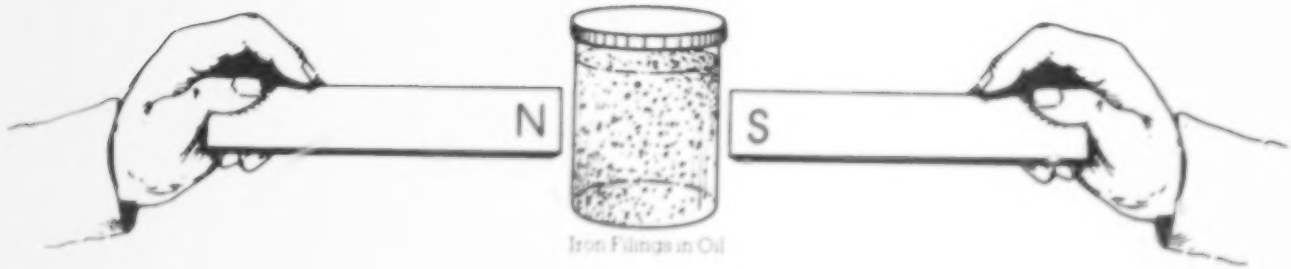
PROCEDURE:

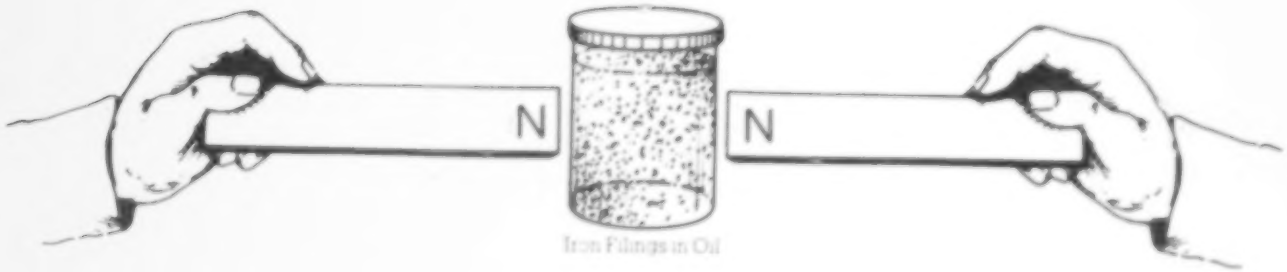
(1) Place a small amount of iron filings in the vial.

(2) Add transparent oil until it reaches the top of the vial. Cap the vial.

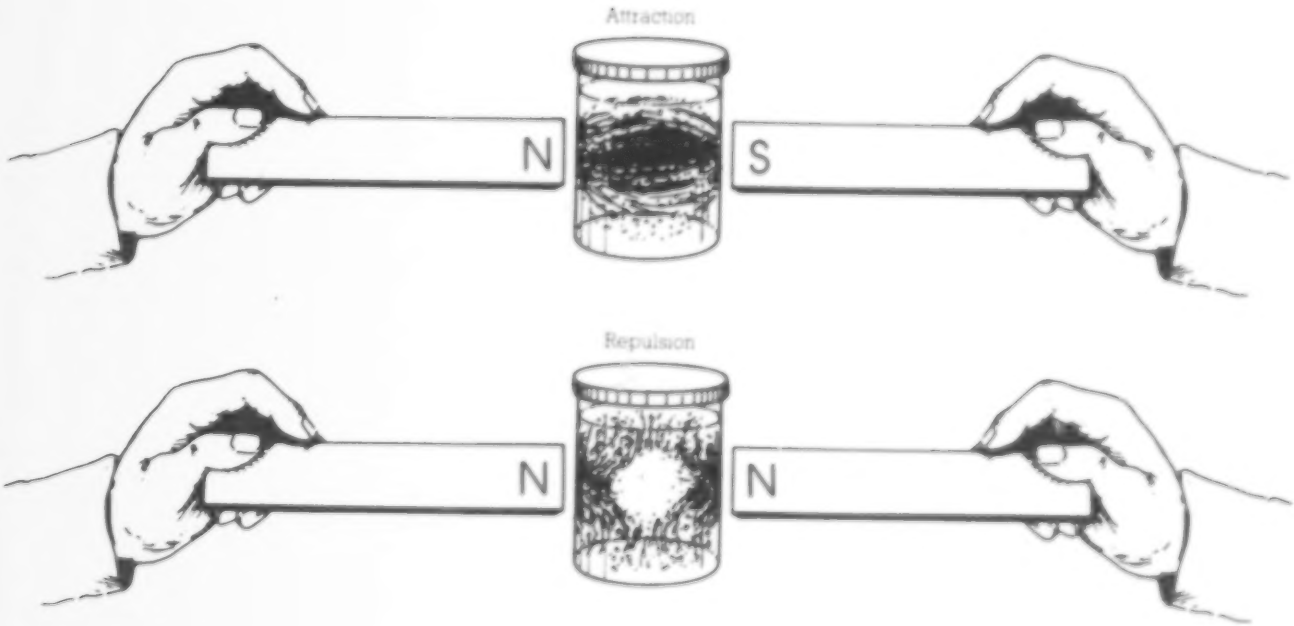
(3) Vigorously shake the vial. Place the unlike poles of the two magnets against the vial on opposite sides, as shown in Diagram A. Make a three-dimensional sketch of the pattern of the filings.

(4) Repeat (3) using the two like poles of the magnets.





RESULTS:



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G-69. MAGNETISM AT A DISTANCE

(1, 2, 4, 5, 14, 17)

PURPOSE:

To investigate how the strength of a magnetic field varies with distance from the magnet.

MATERIALS:

bar magnet
string
paper clip
tape
metric ruler

PROCEDURE:

(1) Tie one end of the string to the paper clip and tape the other end to the table.

(2) Attach the magnet to the paper clip. Slowly pull the magnet straight up until the string is taut.

(3) Continue to slowly pull the magnet straight up as shown in Diagram A.

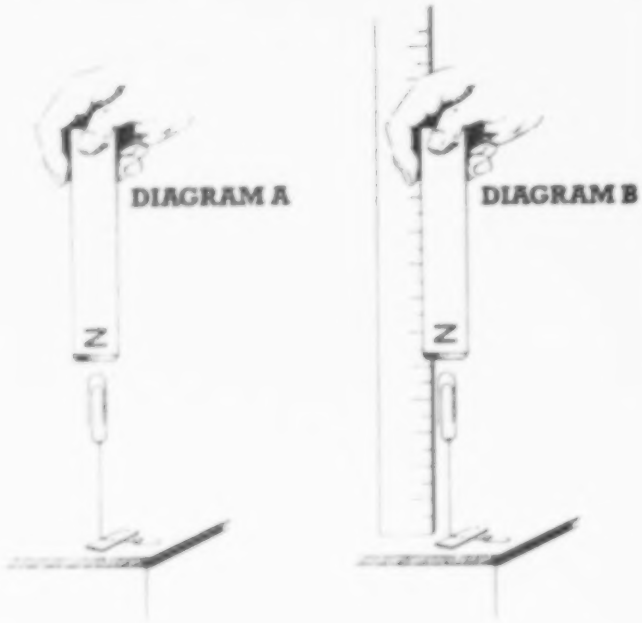
(4) Observe what happens. What force caused the paper clip to stand up above the table? What force caused the paper clip to fall to the table? Why?

(5) Hold the metric ruler next to the tape as shown in Diagram B. Repeat (2), but this time, as the magnet is pulled straight up, hold it against the ruler. When the string is taut, record the height of the top of the paper clip on the meter stick.

(6) Continue to slowly pull the magnet straight up. As soon as the paper clip drops, stop moving the magnet, and read the height of the bottom of the magnet. By what distance were the magnet and paper clip separated just as the clip dropped?

(7) Repeat (5) and (6) for other magnets. Try with an electromagnet. Which magnets are strongest? How do you know? Which are weakest?

(An alternative procedure would be to secure the magnet with a ring stand and clamp, set up the paper clip as before so that it is touching the magnet, then pull down on the string until the clip drops.)



RESULTS:

As the paper clip detaches from the magnet, it remains suspended in the air because the force of magnetic attraction is sufficient to overcome the force of gravity. As the distance between the magnet and paper clip increases, a point is reached where the paper clip falls to the table. At this point, the force of gravity is larger than the force of magnetic attraction. The strength of a magnetic field decreases with distance from the magnet. Different magnets have magnetic fields of different strengths.

G-70. MAKING A COMPASS
(1, 2, 14, 17)

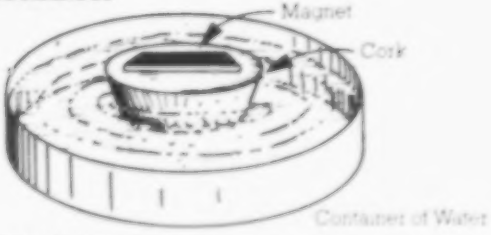
PURPOSE:

To investigate how a compass works

MATERIALS:

small magnet
cork
compass
a non-steel container of water

DIAGRAM A



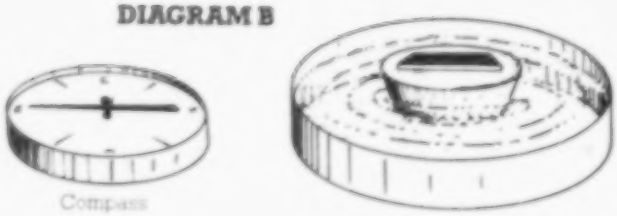
PROCEDURE:

(1) Float the cork in the container of water. Place the magnet on top of the cork. (See Diagram A.) What happens?

(2) Remove and turn the magnet in a different direction, then replace it. What happens?

(3) Place the compass close (but not too close) to the magnet. (See Diagram B.) How does the position of the compass needle compare with the position of the magnet? Which pole of the magnet points in the same direction as the compass needle? What can you conclude?

DIAGRAM B



RESULTS:

The magnet will always align itself in the same direction. The north-seeking pole points north. This direction is the same as the direction in which a compass needle points.

G-71. STATIC ELECTRICITY
(1, 2)

PURPOSE:

To observe the effects of static electricity

MATERIALS:

glass rod
piece of plastic wrap
scraps of paper
balloons
comb
puffed rice
piece of wool

Note: Static electricity investigations work best in a cool, dry climate (such as a classroom in winter). The glass rod will hold a charge better if dipped in alcohol before charging.

PROCEDURE:

(1) Hold an air-filled balloon against the wall. Release the balloon. What happens?

(2) Rub the balloon with a piece of wool and then hold it against the wall. Release the balloon. What happens?

(3) Tear some paper into small pieces. Bring a comb near the pieces. What happens?

(4) Rub the comb with wool, and again bring it near the paper. What happens?

(5) Repeat (3) and (4) with puffed rice and a different comb. What happens?

(6) Bring a glass rod near a stream of water from a cold water faucet. What happens?

(7) Rub the glass rod with plastic wrap and again bring it near (without touching) the stream of water. What happens?

(8) What are some everyday examples of static electricity?

RESULTS:

In (1) the balloon falls. In (2) it clings to the wall. In (3) and (6), nothing happens. In (4) and (7), the objects are attracted to the rod. The puffed rice (5) reacts in the same way as the paper. Rubbing appropriate objects with wool or silk gives them a static charge. When these objects are brought near a neutral object, the neutral object is attracted to them. (The pieces of paper and the puffed rice may pop off the comb after the initial attraction. On contact with the comb, the paper and rice acquire the same charge as the comb. The rice or paper and the comb then repel one another.)

G-72. ELECTROSCOPE

(1, 2, 6, 14)

PURPOSE:

To detect static electricity.

MATERIALS:

electroscope
rubber rod
wool
glass rod
plastic wrap

PROCEDURE:

(1) Examine the electroscope.

(2) Touch the knob of the electroscope with the rubber rod. What happens?

(3) Rub the rubber rod with wool. Now touch the knob with the rod. What happens? Explain the results.

(4) Repeat (2) and (3) using the glass rod and plastic wrap. What happens? Explain the results.

RESULTS:

Before the glass and rubber rods were rubbed, they did not affect the leaves of the electroscope. After rubbing, the leaves separated. A rubber rod rubbed with wool gains a negative charge. A glass rod rubbed with plastic gains a positive charge.

G-73. ELECTROSTATIC CHARGE

(1, 2, 6, 14, 17)

PURPOSE:

To investigate how charged objects behave.

MATERIALS:

two pith balls, each suspended from a string
two support stands
rubber rod
glass rod
wool
plastic wrap

PROCEDURE:

(1) Suspend each pith ball from a stand (as shown in the diagram).

(2) Rub the rubber rod with wool. Touch the rod to one of the pith balls. What happens?

(3) Continue to hold the rubber rod to the pith ball until the ball breaks away. Now try to bring the rubber rod to the pith ball. What happens?

(4) Repeat (2) and (3) with the other pith ball.

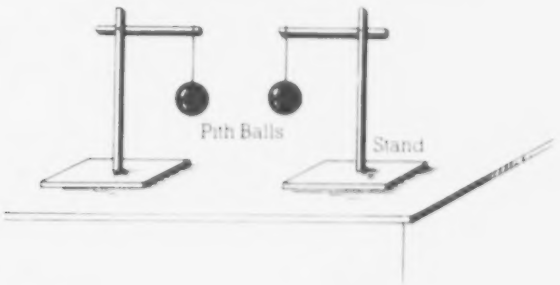
(5) Try to bring the two pith balls together. What happens?

(6) Touch both pith balls gently with the back of your hand. Now try to bring them together. What happens?

(7) Repeat (2) – (6) using the glass rod rubbed with plastic.

(8) Charge one pith ball negatively and the other pith ball positively and bring them together. What happens?

(9) Based on your observations, describe the relationship between like charges, between unlike charges, and between charged and uncharged objects.



RESULTS:

Like charges repel one another. Unlike charges attract one another. Charged objects attract uncharged objects.

G-74. AN ELECTROPHORUS

(1, 2, 6)

PURPOSE:

To produce static electricity by building an electrophorus.

MATERIALS:

flat metal dish or large metal jar lid
a piece of plastic or a candle
vinylite phonograph record
wool

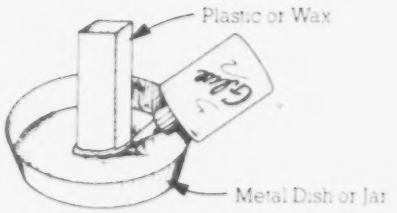
PROCEDURE:

(1) Glue the piece of plastic or candle to the metal dish as shown in the diagram.

(2) Rub the record with wool for about 30 seconds.

(3) Hold the dish by the plastic or candle handle you made for it and touch the dish to the area where the record was rubbed. Touch the dish with your other hand, then quickly remove it.

(4) Still holding the dish by the handle, bring it near a radiator or doorknob. What happens?



RESULTS:

A spark jumps between the dish and radiator or doorknob as the dish discharges. The record picked up a negative charge when rubbed with wool. When the metal dish was touched to the record, the electrons in the dish were repelled away from the record.

When the dish was touched, the repelled electrons flowed into the hand. The dish became positively charged and discharged when brought near the radiator or doorknob. The electrophorus was an early device used to produce static electricity.

G-75. PRODUCING STATIC ELECTRICITY BY CONDUCTION

(1, 2, 6, 14, 20)

PURPOSE:

To charge an object through conduction.

MATERIALS:

electroscope
rubber rod
wool
glass rod
plastic wrap

PROCEDURE:

(1) Touch the knob of the electroscope with the rubber rod. What happens?

(2) Rub the rod with wool and again touch the knob. What happens?

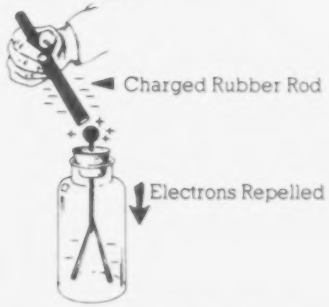
(3) Repeat (1) and (2) using the glass rod and plastic wrap. What happens?

(4) Use your conclusions about like and unlike charges from Activity G-73 to explain why the results occurred as they did in each step.

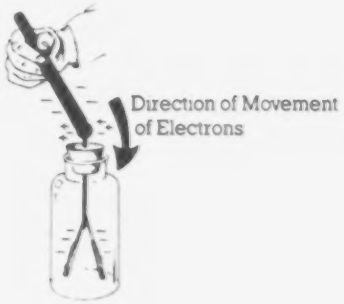
RESULTS:

The leaves of the electroscope separated only after the rods were charged by rubbing.

Negative charge by contact (rubber rod)



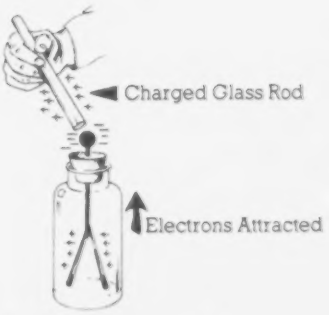
The negatively charged rod repels the electrons of the electroscope before touching.



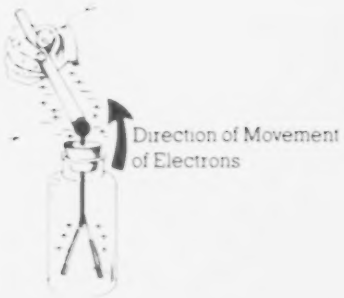
On touching, some electrons flow from the rod into the electroscope.

The electroscope has a negative charge after removing the rod.

Positive charge by contact (glass rod)



The positively charged rod attracts the electrons from the electroscope before touching.



On touching, some electrons flow from the electroscope into the rod.

When the glass rod is removed, the electroscope has a positive charge.

G-76. PRODUCING STATIC ELECTRICITY BY INDUCTION

(1, 2, 6, 14, 20)

PURPOSE:

To charge an object through induction.

MATERIALS:

electroscope
rubber rod
glass rod
wool
plastic wrap

PROCEDURE:

(1) Bring a rubber rod *near* (but don't touch) the knob of an electroscope. What happens?

(2) Rub the rod with wool and again bring it near the knob. What happens?

(3) Keep the rod near the knob and touch the knob with your finger. What happens?

(4) Remove your finger from the knob and then move the rod away from the electroscope. What happens?

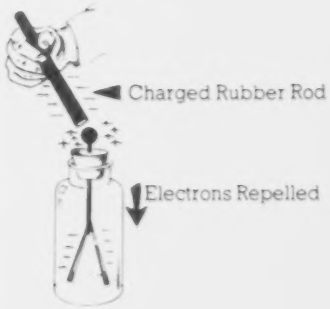
(5) Repeat (1) through (4) using a glass rod and plastic wrap.

(6) Use your conclusions about like and unlike charges from Activity G-73 to explain why the results occurred as they did in each step.

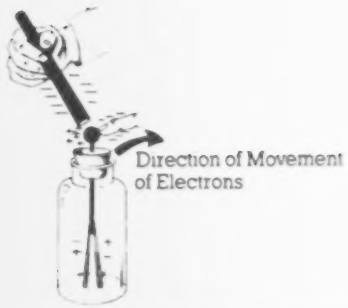
RESULTS:

No movement of the electroscope leaves occurred before the rods were rubbed. After the rods were rubbed and brought near the electroscope, the leaves separated. When the finger touched the knob, the leaves went back together. When the finger and rods were removed, the leaves separated again.

Positive charge by induction



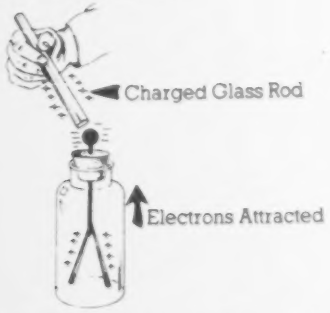
The negatively charged rubber repels the electrons of the electroscope when brought near the electroscope.



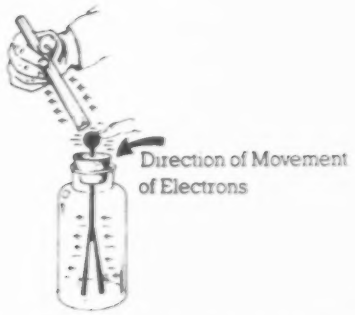
When the finger touches the electroscope knob, electrons flow into the finger.

When the rubber rod is removed, the electroscope has a positive charge.

Negative charge by induction



The positively charged glass rod attracts the electrons of the electroscope when brought near the electroscope.



When the finger touches the electroscope knob, electrons flow from the finger into the electroscope.

When the glass rod is removed, the electroscope has a negative charge.

G-77. CONDUCTORS AND INSULATORS OF ELECTRICITY

(1, 2, 6,14)

PURPOSE:

To distinguish between electrical conductors and insulators.

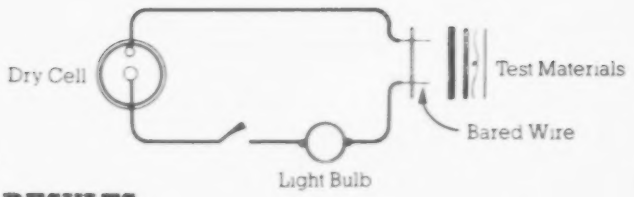
MATERIALS:

switch
flashlight bulb
wires

dry cell
ammeter or galvanometer (optional)
various materials to test such as silver, aluminum, wood, rubber, thread, glass, coins, mica, and plastic

PROCEDURE:

(1) Set up the apparatus as shown in the diagram.
(2) Place one of the materials to be tested across the bared wire and close the switch. Does the bulb light?
(3) Test all of the materials and make a list of the conductors and the insulators.
Note: Use of the galvanometer or ammeter will quantify the conductance.



RESULTS:

Metals are conductors. Materials like wood, mica, rubber, and plastic are insulators. Listed below are some metals in order of their conductivity.

1. silver
2. copper
3. gold
4. aluminum
5. magnesium
6. tungsten
7. iron
8. tin
9. lead
10. mercury

G-78. MEASURING VOLTAGE

(1, 2, 4, 5)

PURPOSE:

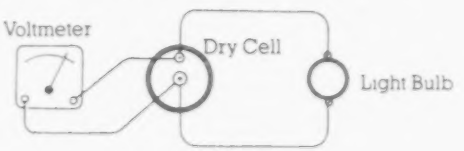
To measure the voltage of a dry cell in a simple circuit.

MATERIALS:

dry cell
voltmeter
wires
light bulb

PROCEDURE:

(1) Connect the light bulb and dry cell as shown in the diagram.
(2) Connect the positive terminal of the battery to the positive terminal of the voltmeter. Connect the negative terminal of the battery to the voltmeter's negative terminal.
(3) Read the voltmeter. How does the reading compare with the voltage printed on the dry cell?



RESULTS:

The voltmeter reading should be similar (depending on the condition of the dry cell) to the voltage printed on the dry cell. It should be noted that voltmeters are always connected outside the main circuit (in parallel with the main circuit).

G-79. MEASURING CURRENT

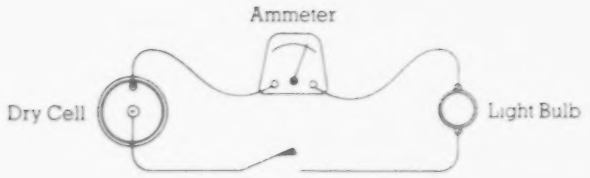
(1, 2, 4, 5)

PURPOSE:

To measure the current in a simple circuit.

MATERIALS:

ammeter
dry cell
light bulb
wires
switch



PROCEDURE:

(1) Set up the apparatus as shown in the diagram.
(2) Close the switch. What is the current in the circuit?

RESULTS:

The current will be quite small. It should be noted that ammeters are connected into the main circuit (in series) while voltmeters are connected outside the main circuit (in parallel).

G-80. FACTORS AFFECTING RESISTANCE

(1, 2, 5, 6, 9, 11,16)

PURPOSE:

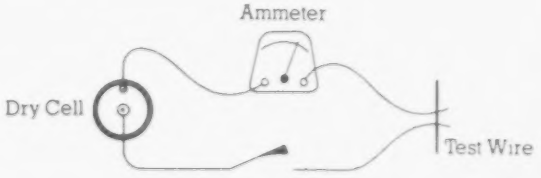
To determine how the kind, thickness, and length of wire affects the amount of current in a circuit.

MATERIALS:

wires of the same dimension, but of different materials such as copper, iron, and nichrome
wires of the same material, but of different thicknesses
wires of the same material and thickness, but of different lengths
dry cell
switch
wires
ammeter

PROCEDURE:

(1) Connect the apparatus as shown in the diagram.
(2) How do you think the *kind* of wire connected into the circuit you've constructed will affect the amount of current flowing in the circuit? Decide which wires you should choose to test your hypothesis, then go ahead and test it. In deciding which wires you'll choose to test this hypothesis, make sure you correctly *control* your investigation. What are your results? Was your hypothesis confirmed?
(3) How do you think the *thickness* of wire will affect the amount of current? In deciding which wires you'll choose to test this hypothesis, make sure you correctly *control* your investigation. What are your results? Was your hypothesis confirmed?
(4) How do you think the *length* of wire will affect the amount of current? Again make sure you properly *control* your investigation. What are your results? Was your hypothesis confirmed?
(5) Describe how you carried out this activity so that it was correctly controlled.



RESULTS:

Nichrome and iron wire have greater resistance than copper wire. Less current will flow through them. Resistance decreases as the thickness of wire increases and increases as the length of wire increases.

G-81. OHM'S LAW

(Teacher Demonstration) (1, 2, 5, 6, 12, 13, 14, 17)

PURPOSE:

To demonstrate the relationship among voltage, current, and resistance.

MATERIALS:

six dry cells or a power supply
10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 ohm resistors
wires
ammeter

PROCEDURE:

(1) Have students prepare a three-column table with "Voltage," "Current," and "Resistance" as headings.

(2) Relationship between voltage and current

Connect a 10-ohm, 15-watt resistor to an ammeter and power supply as shown in the diagram. If a voltmeter is not built into the power supply, connect a voltmeter across output terminals A and B.

Adjust the power supply control so that the voltmeter reads 1 volt. Record the voltage and the reading of the ammeter. Repeat, increasing the voltage in 1-volt steps. Do not exceed 10 volts.

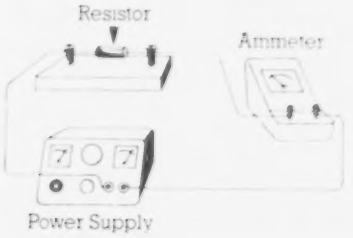
(If 1.5 V dry cells are used, the voltage readings will be 1.5, 3.0, 4.5, 6.0, 7.5, and 9.0 volts.)

Plot these data on graph paper with current on the y axis and voltage on the x axis. Draw the line which represents the best fit among the points. For a given resistance, what is the relationship between voltage and current?

(3) Relationship between current and resistance

With the 10-ohm, 15-watt resistor in the circuit, set the power supply so that the voltmeter reads 10 volts. Record the ammeter reading and the resistance. Repeat, using 20-ohm, 30-ohm, ...100-ohm resistors.

Plot these data on graph paper with current on the y axis and resistance on the x axis. Connect the points with a best fit line. For a given voltage, what is the relationship between resistance and current?



RESULTS:

Current is directly related to voltage: the higher the voltage, the greater the current. Current and resistance are inversely related: the greater the resistance, the lower the current.

G-82. CHARACTERISTICS OF SERIES CIRCUITS

(1, 2, 5, 8, 14)

PURPOSE:

To determine the characteristics of a series circuit.

MATERIALS:

two light bulbs
dry cell
switch
wires
ammeter

DIAGRAM A

PROCEDURE:

(1) Connect the apparatus as shown in Diagram A.

(2) Close the switch. Note the brightness of the light bulb and record the current in amperes.

(3) Add another light bulb in series as shown in Diagram B.

(4) Note what happens to the brightness of the light bulbs when the second one is added and then record the current in amperes.

(5) Unscrew one of the light bulbs. What happens to the other light bulb and the current?

(An alternative procedure would be to give students the equipment and ask them to connect the light bulbs in the circuit so that when one light bulb was unscrewed, the other would also go out.)

DIAGRAM B

RESULTS:

Adding light bulbs to a series circuit increases the resistance, causing the current to be reduced and the bulbs to shine less brightly. When one light bulb was unscrewed, the other went out and the current stopped flowing in the circuit. The circuit was broken.

G-83. DRY CELLS IN SERIES

(1, 2, 4, 5, 14, 17)

PURPOSE:

To determine what happens to the total voltage when dry cells are connected in series.

MATERIALS:

voltmeter
two dry cells
light bulb
wires
switch

DIAGRAM A

PROCEDURE:

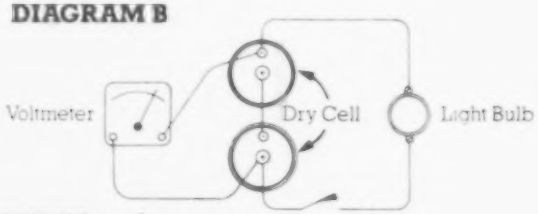
(1) Connect the apparatus as shown in Diagram A.

(2) Close the switch. Note the brightness of the light bulb and record the voltage.

(3) Add another dry cell in series as shown in Diagram B. The positive terminal of one dry cell should be connected to the negative terminal of the other.

(4) Close the switch. Note the brightness of the bulb and compare it to the brightness in (2). Record the voltage.

DIAGRAM B



RESULTS:

The light bulb was brighter with two dry cells. The total voltage was also greater (about twice as much) than the voltage of a single dry cell.

G-84. CHARACTERISTICS OF PARALLEL CIRCUITS

(1, 2, 6, 8,14)

PURPOSE:

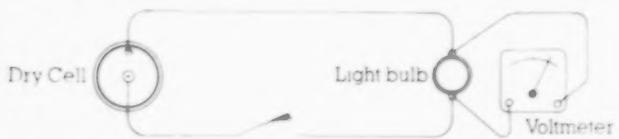
To determine the characteristics of a parallel circuit.

MATERIALS:

dry cell
switch
two light bulbs
wires
voltmeter

Note: The battery must be large enough to provide the rated current for two bulbs or the first bulb will dim when the second is added.

DIAGRAM A



PROCEDURE:

(1) Connect the apparatus as shown in Diagram A.
(2) Close the switch and note the brightness of the bulb. Record the voltage.
(3) Add a second light bulb in parallel as shown in Diagram B.
(4) Close the switch and compare the brightness of the two bulbs to the brightness of one bulb. Record the voltage.
(5) Move the voltmeter so that it reads the voltage across the second bulb. How does this voltage compare to the voltage in (4)?
(6) Unscrew one bulb. What happens?

(An alternative procedure would be to give students the equipment and ask them to connect the light bulbs in the circuit so that when one light bulb was unscrewed, the other would remain lit.)

DIAGRAM B

RESULTS:

The two bulbs in parallel were each as bright as the single bulb. The voltage across each bulb is the same. When one bulb was unscrewed, the other one remained lit.

G-85. DRY CELLS IN PARALLEL

(1, 2, 4, 5, 14, 17)

PURPOSE:

To determine what happens to total voltage when dry cells are connected in parallel.

MATERIALS:

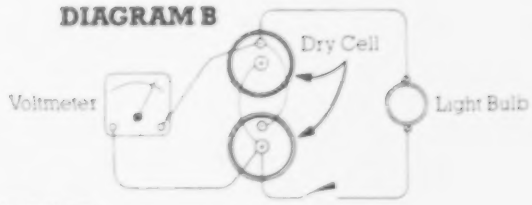
two dry cells
switch
light bulb
voltmeter
wires

DIAGRAM A

PROCEDURE:

(1) Connect the apparatus as shown in Diagram A.
(2) Close the switch and note the brightness of the bulb. Record the voltage.
(3) Add a dry cell in parallel as shown in Diagram B. The positive terminals should be connected together and the negative terminals should be connected together.
(4) What do you predict the voltage will be? Why?
(5) Close the switch and compare the brightness of the bulb to the brightness in (2). Record the voltage. Was your prediction correct?

DIAGRAM B



RESULTS:

The brightness of the bulb does not change when two dry cells are connected in parallel. The total voltage of two dry cells connected in parallel is the same as the voltage of a single dry cell.

G-86. VOLTAIC PILES

(1, 2, 5, 6, 17)

PURPOSE:

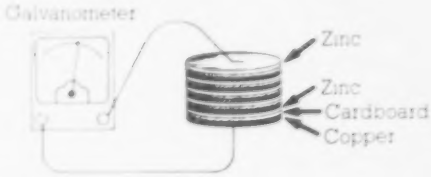
To demonstrate how a battery is made by constructing a voltaic pile.

MATERIALS:

five pieces of zinc about the size of a nickel
five pieces of copper the same size as the zinc
five pieces of cardboard blotting paper cut to the same size as the zinc and copper
solution of epsom salts and water
galvanometer (or the electric current detector built in Activity G-90)

PROCEDURE:

(1) Soak the cardboard in the solution of epsom salts and water.
(2) Build the pile on a lab table by first putting down a piece of copper, then a soaked cardboard piece, then a zinc piece. Repeat until all of the pieces are used. A zinc piece should be on the top.
(3) Connect the galvanometer to the ends of the pile. What happens?



RESULTS:

The needle on the galvanometer deflects, showing that the pile produces a current. The first reliable source of electricity was the voltaic pile. This pile or battery enabled scientists to study more easily the characteristics of electricity. Voltaic piles may be built using different metals and conducting solutions.

G-87. LEMON CELLS

(1, 2, 6, 17)

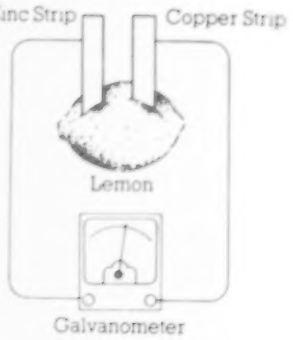
PURPOSE:

To use a lemon to build a simple electrical cell.

MATERIALS:

zinc strip
copper strip
lemon
galvanometer (or the small current detector made in Activity G-90)

DIAGRAM A



PROCEDURE:

(1) Roll the lemon on a hard surface to break up the tissues and release the juice.

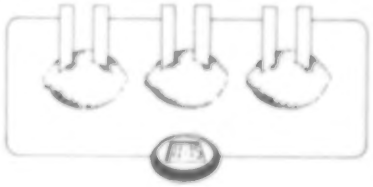
(2) Insert the zinc and copper strip next to each other. Do not let them touch. (**Note:** Other kinds of metals may be substituted.)

(3) Connect the galvanometer to the metal strips as shown in Diagram A.

(4) Observe what happens to the galvanometer.

(5) (Optional) Connect three lemon cells as shown in Diagram B to a quartz clock. What happens?

DIAGRAM B



RESULTS:

The galvanometer needle deflected, showing that the lemon cell produces a current. When two dissimilar metals in a conducting solution are connected by a wire, electrons will flow from one metal to the other. The lemon juice serves as the conducting solution. Students may wish to try other acidic fruits and metals to see if they produce currents.

G-88. PRODUCTION OF ALTERNATING CURRENT

(1, 2, 4, 9, 14, 16, 17)

PURPOSE:

To produce an alternating current.

MATERIALS:

two insulated copper wire coils (one with more turns than the other)
two bar magnets
galvanometer (or the small current detector made in Activity G-90)

PROCEDURE:

(1) Attach the ends of the wire coil with fewer turns to the galvanometer.

(2) Push a bar magnet down through the coil and watch the galvanometer needle. What happens?

(3) Pull the magnet up through the coil and observe what happens to the galvanometer needle.

(4) Repeat (1), (2), and (3), using the wire coil which has more turns. Observe what happens to the galvanometer needle.

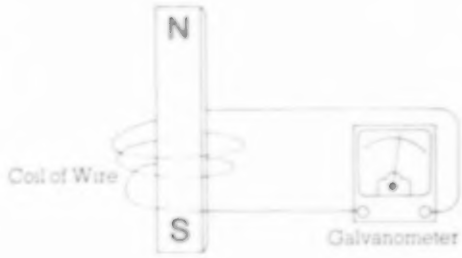
(5) Repeat (1), (2), and (3), this time moving the magnet through the coil at a faster rate. Observe the galvanometer needle.

(6) Repeat (1), (2), and (3), using two bar magnets with their north and south poles held together. Observe the galvanometer needle.

(7) Hypothesize what would happen if the coil were moved up and down with the magnet held still inside it. Try this and observe the galvanometer needle.

(8) How does the movement of the galvanometer needle show that an alternating current is produced each time?

(9) In this investigation, what factors affect the strength of the current produced?



RESULTS:

In all parts of this activity, the galvanometer needle moves back and forth, showing that an alternating current is produced. There is greater deflection of the needle when a larger coil of wire is used, when more magnets are used, and when the magnet is moved back and forth at a faster rate. An alternating current is also produced when the coil of wire is moved instead of the magnet.

G-89. ELECTRIC POWER

(1, 4, 5, 6, 12)

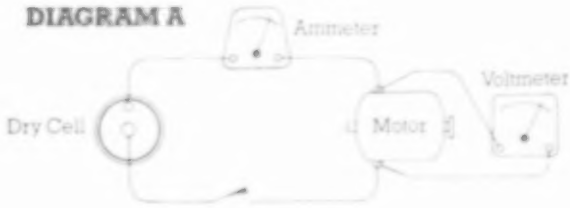
PURPOSE:

To calculate the power in an electric circuit.

MATERIALS:

dry cell
motor
ammeter
switch
voltmeter
wires
two light bulbs

DIAGRAM A



PROCEDURE:

(1) Connect the apparatus as shown in Diagram A.

(2) Close the switch and record the ammeter and voltmeter readings.

(3) Calculate the power in the circuit using the equation:

$P = V \times I$ in which: P = power (watts)
V = voltage (volts)
I = current (amperes)

(4) Borrow a motor from another student and hook it in parallel to the first motor as shown in Diagram B. What do you hypothesize will happen to the power in the circuit when the second motor is added?

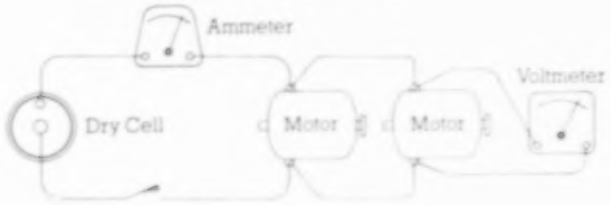
(5) Repeat (2) and (3).

(6) Connect a light bulb in parallel with the two motors. Repeat (2) and (3).

(7) Connect a second light bulb in parallel and repeat (2) and (3).

(8) What happened to the power as more "appliances" were added? Was your hypothesis correct? What happened to the voltage? The current? How is this circuit similar to a circuit in your home?

DIAGRAM B



RESULTS:

The wattages of the motor and light bulbs can be determined from their voltage and amperage ratings. The power calculated by the students may vary from the sum of the wattage ratings of the "appliances." As more "appliances" are added, the current and power increase while the voltage should remain the same. As "appliances" are added, the battery discharges at a faster rate.

G-90. A SMALL CURRENT DETECTOR

(1, 2, 6)

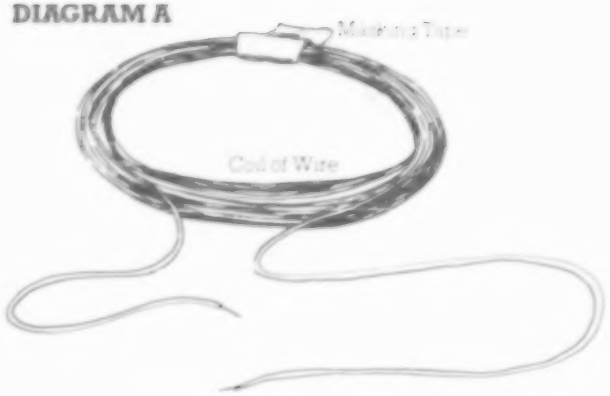
PURPOSE:

To build a galvanometer, a device that detects small currents.

MATERIALS:

compass
insulated copper wire
dry cell
masking tape
small cardboard box

DIAGRAM A



PROCEDURE:

(1) Strip 2 cm of insulation off the ends of the wire.

(2) Wrap the wire in a coil of about 150 turns. Leave 15 cm of wire at each end of the coil.

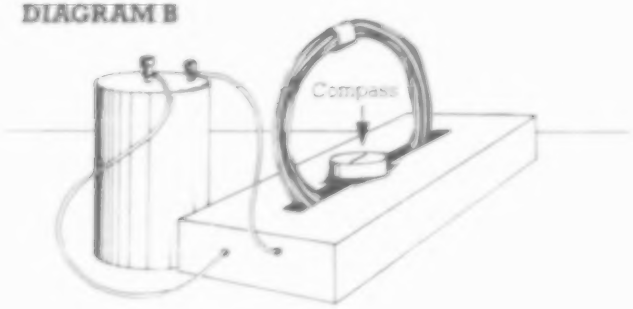
(3) To keep the coil intact, wrap a piece of masking tape around it.

(4) Make a stand for the galvanometer by cutting a slit in the cardboard box and putting the wire coil part way into the slit.

(5) Place the compass inside the coil. Turn the box so that the coil is aligned with the compass needle.

(6) Attach the ends of the coiled wire to the dry cell. What happens to the compass needle?

DIAGRAM B



RESULTS:

The compass needle deflects as soon as the coiled wire is connected to the dry cell. The current flowing in the coil produces a magnetic field which affects the needle of the compass. (This device can be used in activities where small electric currents need to be detected.)

G-91. SAFETY AND ELECTRICITY

PURPOSE:

To investigate safety precautions to be taken around electricity.

PROCEDURE:

(1) Invite an electrician to speak to the class about the safety features in your homes that protect you from electrical hazards.

(2) Invite someone from the fire department to speak about fire hazards from improper use of electricity.

(3) Invite a representative from the local electrical utility to speak about safety procedures to be followed:
—when there is an electrical problem in your home,
—when there are downed electrical wires, or
—when you are around transmission towers.

G-92. FUSES
(1, 2)

PURPOSE:

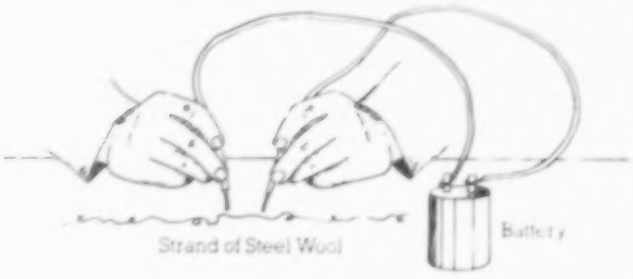
To demonstrate how a circuit fuse works.

MATERIALS:

dry cell
wires
strand of steel wool

PROCEDURE:

(1) Strip about 2 cm of insulation off the ends of two wires.
(2) Attach the wires to the dry cell terminals as shown in the diagram.
(3) Place the single strand of steel wool on a heat resistant surface.
(4) Touch the ends of the wires to the strand of steel wool. The wires should be only about 1 cm apart. What happens?



RESULTS:

There is a flash of light as the steel wool strand quickly melts. A fuse works in the same way. If too much current passes through a fuse, the metal in the fuse melts and breaks the circuit.

Reprinted with permission from: Graf, Rudolf F. *Safe and Simple Electrical Experiments*. (Mineola, New York: Dover Publications, 1973.)

G-93. GROUNDING
(19)

PURPOSE:

To investigate why grounding electrical circuits and appliances is important, and how grounding is done.

PROCEDURE:

(1) Write to Underwriters' Laboratories (UL) for information on grounding and electrical safety. The address is 333 Pfingsten Rd., Northbrook, Chicago, Il 60062.
(2) Write a report and/or do a project to illustrate why grounding is needed in home and industrial wiring and how it is done.
(3) Bring to class appliance manuals that have safety statements and procedures about grounding. What do the manuals recommend?

G-94. TYPES OF RADIATION
(14)

PURPOSE:

To differentiate among alpha particles, beta particles, and gamma rays.

MATERIALS:

copies of Diagrams A, B, and C

PROCEDURE:

(1) From the information given you, make your own diagram representing these three types of radiation.

(2) Which type can travel the farthest? Which type can travel only short distances?

(3) Which type can penetrate through the densest material? Which type can be stopped by thin material?

(4) What are some ways of stopping radiation?

DIAGRAM A

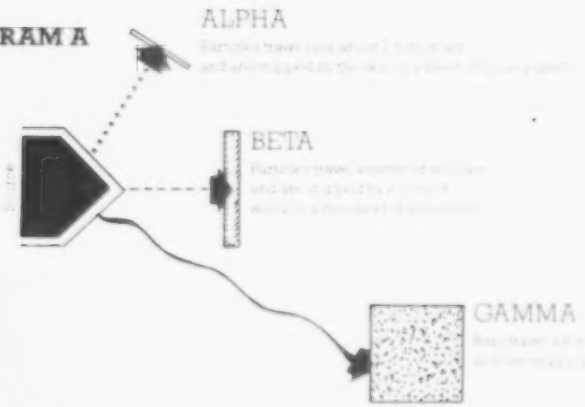


DIAGRAM B

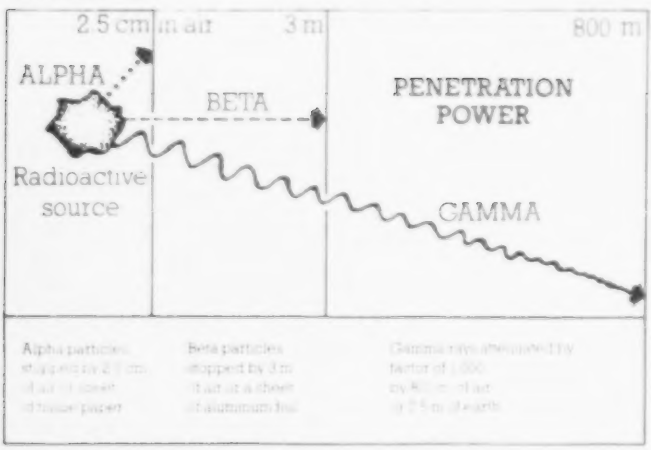
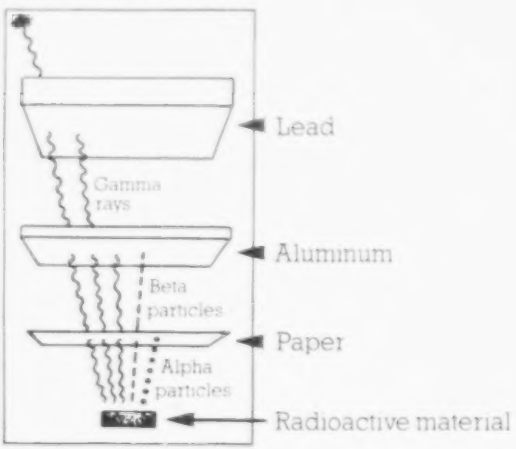


DIAGRAM C



RESULTS:

Alpha particles travel the shortest distance and can be stopped by thin materials such as skin or paper. Gamma rays travel the longest distance and must be stopped by a dense or heavy material such as lead or cement.

G-95. HALF-LIFE
(1, 2, 12, 13, 14, 18)

PURPOSE:

To create a model that demonstrates the half-life of a radioactive element.

MATERIALS:

100 flat disks painted red on one side (washers or heavy cardboard can be used)
covered can or box

PROCEDURE:

(1) Put the disks in the can, cover the can, and shake.
(2) Remove the lid and pour out the disks.
(3) Record the number of disks that land red side up, and then remove these disks.
(4) Put the remaining disks in the can and repeat (1), (2), and (3).
(5) Repeat (1) through (4) until all of the disks have come up red.
(6) Plot the data on a graph. The number of trials should be on the x axis and the number of disks that came up red on the y axis.
(7) Assume that each trial represents one second in the decay of a radioactive element. Use the graph to determine the half-life of the element.

RESULTS:

The half-life of the element is one second. According to probability, in each trial half of the disks would turn up red. Although in any one trial more or less than half the disks may come up red, students should get the idea that half-life is that period of time when half of the material decays.

Reprinted with permission from: Barmon, Charles R; John J. Rusch; Myron O. Schneiderwent; and Wendy B. Hinden. "Activity 25 — Half-Life." p.183. *Physical Science*. (Morristown, NJ: Silver Burdett Co., (c), 1982.)

G-96. OPERATING A GEIGER COUNTER
(1, 2, 4)

PURPOSE:

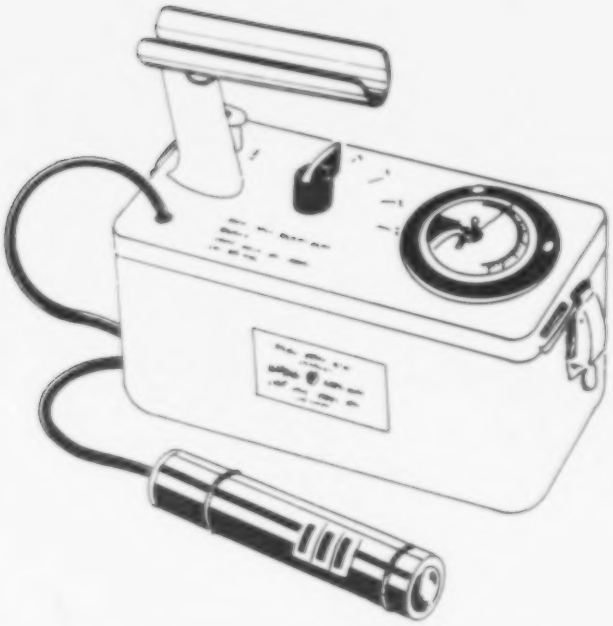
To use a Geiger counter to detect radioactivity.

MATERIALS:

Geiger counter (This may be available from your local Civil Defense Office.)
safe radioactive samples (A Civil Defense Geiger counter will have a sample attached to the side of the case.)

PROCEDURE A: OPERATING THE GEIGER COUNTER

(1) A Geiger-Muller counter has a probe equipped with a beta shield, a high voltage circuit, and a meter or earphone to register the rate or intensity of radiation. Check the counter to see that it is operating properly.
(2) Turn the selector switch to the X-100 or X-10 range and allow at least 30 seconds for the counter to warm up.
(3) Rotate the shield on the probe to the fully open position. Place the open area of the probe as close as possible to a radioactive sample. If no clicks are heard or recorded on the meter, the batteries may be dead. Check the batteries and replace if necessary.
(4) A Geiger counter is a sensitive scientific instrument and cannot take physical abuse. After use, be certain to TURN IT OFF. Especially protect the tube from sharp objects and hard knocks.



A Civil Defense Geiger Counter (CV-700)

PROCEDURE B: USING THE GEIGER COUNTER

(1) Hold the counter probe near an open window. How intense is the radiation? What types of radiation are being measured?

(2) Close the window. How intense is the radiation now? What type of radiation is being measured?

(3) Use the counter to find a hidden radioactive sample.

(4) Place a radioactive sample a given distance from the counter's probe. Measure its radioactivity in counts per minute. Double, triple, and quadruple the distance, repeating the measurements each time. What happens?

(5) What evidences are there of radioactivity in or near the school building? (Minerals in kits in the earth science lab, rocks outside the building, and materials used in the school's construction may be possible sources.) List the radioactive sources you find.

(6) Bring in objects from home which you think may be radioactive. Old luminous watch and clock faces, for example, may be radioactive. Make a list of radioactive objects.

RESULTS:

At an open window, a Geiger counter measures beta and gamma radiation. (Most Geiger counters do not detect alpha radiation. It is absorbed by the probe.) At a closed window, a counter measures gamma radiation only. (The beta radiation has been absorbed by the glass.) As the distance from a source of radiation increases, the intensity of the radiation decreases.

G-97. URANIUM 238 DECAY

(14, 17)

PURPOSE:

To use a table to determine the sequence of decay for uranium 238.

MATERIALS:

uranium 238 decay table

PROCEDURE:

(1) Use the decay table to answer the following questions. The symbol $^{238}_{92}U$ shows that uranium has an atomic mass number (the number of neutrons plus protons) of 238 and an atomic number (the number of protons) of 92.

(2) What happens to the atomic number of an element if it emits an alpha particle? What happens to the atomic mass number?

(3) What happens to the atomic number of an element if it emits a beta particle? What happens to the atomic mass number?

(4) How many elements in the decay table have an atomic number of 92? 90? 82?

(5) What is the atomic mass number of a beta particle?

(6) What is the atomic mass number of an alpha particle?

(7) What is the atomic number of a beta particle?

(8) What is the atomic number of an alpha particle?

(9) Which element has the longest half-life? Which has the shortest half-life?

(10) How many elements emit alpha particles? Beta particles? Gamma radiation?

(11) What stable element does U 238 decay to? Will that element in turn decay? Why or why not?

(12) Does it take a long or short time for a sample of U 238 to completely decay to lead? Why did you answer as you did?

RESULTS:

When an alpha particle is emitted, an element loses 4 atomic mass number units and 2 atomic number units. An alpha particle is a helium nucleus with the structure $^{4}_{2}He$. When an element loses a beta particle, the new element formed has the same atomic mass number but has increased in atomic number by one. A beta particle is an electron, so it has no mass. It is formed when a neutron breaks into a proton and electron. The proton remains in the nucleus, so the atomic number increases by one. The atomic mass number remains the same. (A neutron has become a proton.) There is only one element with a given atomic number since atomic number determines the element.

G-98. AN UNCONTROLLED CHAIN REACTION

(Teacher Demonstration) (1, 2, 18)

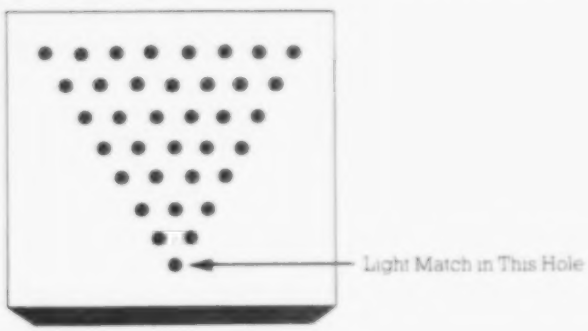
PURPOSE:

To build a model that demonstrates an uncontrolled chain reaction.

Part A

MATERIALS:

a piece of pine board (approximately 2.5 x 10 x 10 cm)
36 wooden safety matches



PROCEDURE:

(1) Drill 36 holes in the piece of pine board as shown in the diagram. Each hole should be the same diameter as a safety match. The holes should be 6 mm apart.

(2) Place a match in each hole and then light the match indicated in the diagram.

(3) What happens?

Part B

MATERIALS:

12 furring strips (30 cm in length)
nails
window screen (66 x 66 cm)
12 mousetraps
13 ping-pong balls

PROCEDURE:

(1) Build a wood-frame cube (30 x 30 x 30 cm) and cover five sides with window screen. Cut a hole slightly larger than the diameter of a ping-pong ball in the screen opposite the open side of the frame. Set the mousetraps, arranging them close together in three rows of four. Carefully place a ping-pong ball on the release bar of each trap. Place the frame over the trap. Drop a ping-pong ball through the hole in the screen.

(2) What happens?

RESULTS:

In Procedure A, all the matches will quickly light. In Procedure B, all the traps will quickly spring. Both procedures illustrate what happens in an uncontrolled chain reaction.

G-99. INDUSTRIAL USES OF RADIOACTIVE ISOTOPES

(14)

PURPOSE:

To become aware of the uses of radioactive isotopes in industry.

MATERIALS:

The Reader's Guide to Periodical Literature
magazines, journals, and newspapers

PROCEDURE:

(1) Use *The Reader's Guide to Periodical Literature* to find articles about the industrial uses of radioactive isotopes. From the articles, list as many industrial uses of radioactive isotopes as you can.

(2) Choose one of the uses you found and describe it briefly.

RESULTS:

Industrial uses of radioactive isotopes include the following:

For Process Control:
Thickness gauges
Level indicators
Specific gravity measures

For Product Testing:
Detecting wear on distributor points in auto engines
Monitoring wear of piston rings
Monitoring abrasion of rubber
Detecting wear on shoes
Determining effectiveness of soaps and detergents
Detecting wear of bearings
Determining effectiveness of fertilizers
Determining effectiveness of dry cleaning agents

For Maintenance and Servicing:
Detecting leaks in buried pipes
Locating manhole covers under snow
Tracing pollution and sewage
Indicating when brake linings need replacement

G-100. RADIOACTIVE ISOTOPES IN QUALITY CONTROL

(14)

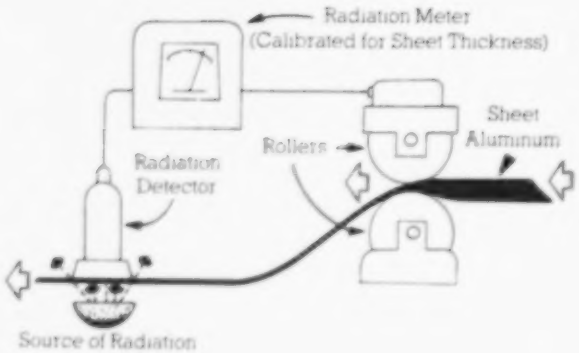
PURPOSE:

To find out about one application of radioactive isotopes in industrial quality control.

PROCEDURE:

(1) Read the following paragraphs.

Finished pieces of aluminum must be of uniform thickness. How is this accomplished? In an aluminum rolling mill, a radioisotope is used to continually measure the thickness of aluminum over a range of 0.0005 to 0.1875 cm. When the radioactive isotope indicates that the aluminum is too thick or too thin, the rolling machine automatically adjusts the rollers so that the aluminum sheet stays uniform in thickness.



The radioisotope thickness gauge consists of a source of beta radiation placed beneath the moving aluminum and a radiation detector mounted above. The aluminum absorbs part of the radiation: the amount absorbed is proportional to the thickness of the aluminum sheet. Thus the radiation meter is calibrated to directly indicate sheet thickness.

Radioisotope thickness gauges are used to control many different types of sheet material: metals, paper, plastics, rubber, and textiles are just a few.

(2) Describe how radioactive isotopes can control the thickness of a sheet of metal.

(3) What is beta radiation?

(4) Describe some other uses of such a radioisotope thickness gauge.

G-101. ISSUES ASSOCIATED WITH NUCLEAR ENERGY

(14)

PURPOSE:

To investigate some of the issues surrounding the use of nuclear energy. (Many of these issues lend themselves to interdisciplinary projects with social studies and English classes.)

MATERIALS:

The Reader's Guide to Periodical Literature
newspapers, magazines, and books

PROCEDURE:

(1) As a class, make a list of nuclear energy issues. This might include the following:

—Do nuclear power plants threaten the safety of people living near them?

—How likely is a nuclear power plant accident?

—Can nuclear wastes be disposed of safely?

—What level of radioactivity is considered safe?

—Are safety procedures at nuclear power plants adequately monitored?

—Does the use of nuclear energy lead to proliferation of nuclear arms?

—Are nuclear power plants more or less cost effective than other power plants in producing electricity?

—Should nuclear energy technology be given to developing nations?

—Should the breeder reactor be developed?

—Does nuclear energy have fewer environmental and health effects than other energy sources?

(2) Select the issue which interests you most. Do library research to find out as much as you can about the issue. Talk to proponents and opponents of nuclear energy to find out their views on the issue.

(3) Make a list of the arguments on each side of the issue.

(4) Decide which side of the issue you stand on and explain why you chose this side.

G-102. FUSION
(14)

PURPOSE:

To investigate recent developments in nuclear fusion technology

MATERIALS:

The Reader's Guide to Periodical Literature
newspapers, magazines, and books

PROCEDURE:

(1) Do library research on one or more of the following questions

—What are the advantages and disadvantages of fusion as a source of electrical energy?

—What fuels are being considered for fusion reactors?

—What conditions are necessary for a fusion reaction to occur?

—What methods for producing fusion are being researched?

—What have been the successes of fusion research? The failures?

—Will nuclear fusion plants ever become a reality? If so, when?

—Are there limits to the amount of energy that can be produced by nuclear fusion?

—How would nuclear fusion plants be similar to nuclear fission plants? How would they be different?

(2) Organize the results of your research and give an oral report to the class on the answer(s) to your question(s)

UNITS

Metric Unit	Abbreviation	Measures
meter	m	distance (d)
second	s	time (t)
gram	g	mass
newton	N	force (F)
joule (newton-meter)	J (N·m)	work (W)
decibel	dB	loudness of sound
degree Celsius	°C	temperature
calorie	cal	heat
volt	V	voltage
ampere	A	current
ohm		resistance
watt (kilowatt)	W (kW)	power
kilowatt-hours	kWh	electrical energy

APPENDIX B — RESOURCE TABLE OF UNITS AND FORMULAS FOR PHYSICAL SCIENCE

FORMULAS

$$\text{Speed} = \frac{\text{distance}}{\text{time}} \qquad S = \frac{d}{t}$$

$$\text{Work} = \text{force} \times \text{distance} \qquad W = F \times d$$

Work In = Work Out
(ideal conditions)

$$F_e \times d_e = F_r \times d_r$$

Effort force × effort distance = resistance force × resistance distance

$$\text{Ideal Mechanical Advantage} = \frac{\text{effort distance}}{\text{resistance distance}} \quad \text{or} \quad IMA = \frac{d_e}{d_r}$$

$$\text{Actual Mechanical Advantage} = \frac{\text{resistance force}}{\text{effort force}} \quad \text{or} \quad AMA = \frac{F_r}{F_e}$$

$$\text{Efficiency (\%)} = \frac{\text{work output}}{\text{work input}} \times 100$$

$$\text{Heat lost or gained by water (cal)} = \text{mass of water (g)} \times \text{temperature change of the water (°C)}$$

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}} \quad \text{or} \quad I\,(\text{amperes}) = \frac{V\,(\text{volts})}{R\,(\text{ohms})}$$

$$\text{Power} = \text{Voltage} \times \text{Current} \quad \text{or} \quad P\,(\text{watts}) = V\,(\text{volts}) \times I\,(\text{amperes})$$

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APPENDIX C — REFERENCES

C-1. BIRTH OF THE WHEEL

And one day it appeared. On the fertile delta of the Tigris and Euphrates Rivers, some time in the Third Millennium B.C., an unknown Sumerian produced what must surely be man's greatest single technological achievement. He made a wheel. Precisely who he was or how he planned to use it will never be known. He may have been a warrior putting together the first war chariot. Or he may have been a mourner providing a smoother ride for some particularly esteemed corpse. The earliest record of a vehicular wheel is a sketch made by an accountant in Sumer about 3500 B.C. The vehicle was apparently a funeral wagon, a bizarre contraption with an undercarriage which swooped up in front like the runners of old-fashioned Hans Brinker ice skates, indicating that this wagon may have been an immediate offspring of the land sledge. The upper body was a tall box on end with a peaked roof. Underneath, there were two pairs of unmistakable wheels. They were probably about two feet in diameter, made of slabs of wood fastened together by crosspieces and then rounded off as carefully as the primitive copper tools of the day would permit. Both axles were fixed rigidly in place. Since the front axle would swing neither left nor right for a turn, the wagon had to be skidded or lifted around corners.

The technology of these first wheels was not very elegant. Nevertheless, they mechanized the Sumerian way of death, and in so doing gave the world a new dimension in mobility. All of a sudden man's ability to move things overland was no longer limited by his capacity — or an animal's — to carry a weight of cargo on his back, or to slither it along on a sledge.

By making the first vehicular wheel, that ingenious Sumerian created a number of things. In scientific terms, he had created a passive roller, an instrument for reducing surface friction in the movement of loads overland. In the days before wheels, a pair of oxen pulling a 3,000-pound load of a sledge had to exert about 1,200 pounds of pull to overcome the surface friction between the ground and the load. A wheel can cut this friction between the ground and the load as much as 100 times. And in fact, with a wheel as round and hard as a railroad train wheel, moving over a surface as smooth and hard as a rail, nine pounds of effort will easily keep 3,000 pounds of load in motion. But those first wooden wheels were neither very round nor very hard. Besides, on a dirt surface the wheel sank in and was always running a little uphill. Despite these imperfections, in time, when wheels and axles and wagons could be built strong enough, a good wheel pulled by a pair of stout oxen could move at least two or three times the load that same team could move with a land sledge.

In far broader terms, along with the wheel, the Sumerians inadvertently created something else. They put together the beginnings of the first modern system of land transportation. That first wheel, mounted beneath a primitive cart, pulled by a pair of oxen down that rough dirt roadway, carried something — in that earliest version, only a corpse — from one place to another more efficiently than that particular item had ever been carried before. This is what wheels were all about when they were first invented. And this is what they are still about today: the vital element in a fascinating and complex thing called a system of transportation. In time, as man improved the technology of wheels and engines,he would find that there were almost no limits to the weight his wheels could carry, or the speeds with which they could be made to turn. However, he would be many long years and many long miles in bringing them to their full potential.

About the year 2000 B.C., several tribes from the steppes near the Black Sea appeared in the Tigris-Euphrates Valley with a strange, fast animal called the horse. Along with it they brought a spoked wheel, greater in diameter and therefore able to roll more easily over rough terrain than the average solid wheel, and far lighter and more maneuverable. Other tribes adopted the new technology: the Philistines, the Egyptians, the peoples of Babylon, Greece, and China.

The wheels of antiquity reached their technological

peak in the Roman Empire — not in Rome itself but among the Celts of Western Europe. The Celtic wagon-makers were superb. Their vehicles were the first to have swiveling front axles, which could swing left or right in a turn. To reduce friction inside their wheel hubs, the Celts installed hardwood rollers so that the wheels no longer scraped their way around the axle but rolled on bearings which in turn rolled on the axle. Radiating outward from the hubs were as many as 14 slender spokes mortised into a felloe, or rim, made of a single piece of heat-bent ash. The tires, too, were in a single piece — strips of iron that were joined together and hammered into a hoop that was completed by welding the ends. The iron tire was built a shade smaller in diameter than the felloe, then heated and fitted on while still hot. When the iron cooled, the tire shrank, locking all the parts of the wheel together.

Life Science Library / WHEELS by Wilfred Owen, Ezra Owen, and the editors of LIFE (c) 1967, TIME-LIFE Books Inc.

C-2. AIRPORT NOISE LINKED WITH HEART DISEASE

Data from an eight-year mortality survey involving 200,000 residents living near the Los Angeles International Airport will be used to indict noise pollution from landing jet aircraft for an increase in deaths from cardiovascular disease and suicide. Although loud noise, especially along jet take-off and landing corridors, has been correlated statistically with elevations in blood pressure (SN: 6/5/82, p.378) — a risk factor in cardiovascular-related deaths and noise — this appears to be the first study directly linking cardiovascular-related deaths and noise.

In a presentation May 10 at a meeting of the Acoustical Society of America in Cincinnati, William Meecham will report on differences he identified in mortality statistics associated with two communities in the L.A. airport area. Matched for population, racial makeup, and socioeconomic factors, the two regions studied are virtually identical except for average residential noise exposures, according to the engineer from the University of California at Los Angeles.

Meecham designated an eight-square-mile region adjacent to the airport — where minimum outdoor jet noise was measured at 90 decibels (dB) — as his "test area." Industrial workers exposed to 90-dB environments must wear hearing protection (SN: 5/22/82, p.347) since research has shown permanent hearing loss can occur at levels as low as 85 dB. In the test area Meecham studied, outdoor noise levels sometimes reached 115 dB. And he found that when windows were closed — something uncommon there during summer months — residential homes seldom attenuated sound levels more than 15 dB. The area is exposed to the thunder from roughly 650 incoming flights daily; at peak daytime periods jets passed overhead only 2.5 minutes apart.

This noisy community was compared with a region bordering it to the south. There the average outdoor noise measured 50 dB, typical of congested urban areas. Since the decibel scale is logarithmic, there is a 10,000 fold difference in sound pressure between 50 dB and 90 dB.

Meecham's data showed the death rate from heart attacks and stroke was 18 percent higher for those 75 years of age and older in the test area, relative to a demographically matched segment in the quieter zone. And the 30 suicides in the test area's 45- to 54-year-old age group were double the quieter zone's age-equivalent rate. Both findings were statistically significant, as was a 60 percent higher incidence of violent death — including murder, suicide and auto accidents — among those 75 and older in the noisy area. Though an elevated violent-death rate was evident for all age groups in the noisy zone, numbers were too small to be statistically significant.

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C-3. NOISE POLLUTION

At the 1984 NBA playoffs between the Dallas Mavericks and the Seattle Supersonics, the roar of the crowd was deafening — literally. Scientific instruments measured the noise level at the game to be an average of 95 decibels, reaching as high as 112 decibels — as loud as a jet taking off. Why take note of this? Well, according to health officials, long exposure to sounds louder than 85 decibels can produce stress and damage hearing.

BEATING ON THE EARDRUMS

We may talk about the sounds of silence, but the truth is, we live in a noisy world, surrounded by sound in almost everything we do. Think of those varied sounds: sporting events, concerts, stereos, TVs, buses, trains, planes, machinery, air conditioning units, movies, traffic, alarm clocks, crowds, hair dryers. They all make noise. While some of these sounds may be music to the ears, others are merely a pain in the ear. The latter is often called noise pollution.

Noise pollution is a relatively new term. Basically, it refers to unwanted sound, or sound that, in some way, interferes with the environment.

Noise is measured in decibels, a unit for expressing the ratio of two amounts of electric or acoustic signal power equal to 10 times the common logarithm of this ratio. (And for all you pursuers of trivia, the "bel" in decibel is named for inventor Alexander Graham Bell, one of the pioneers of sound technology.) A soft whisper is measured at 30 dB, for example, and a heavy truck at 90 dB, to which prolonged exposure can cause hearing damage. A 10-dB increase in sound is perceived by the human ear as twice as loud.

Not only is excessive noise annoying, interfering with concentration, conversation, and sleep, but it is also unhealthy. An estimated 40 million Americans are being exposed to environmental noise levels that may prove damaging to their hearing.

HEAR, HEAR

First and foremost, excessive noise can result in permanent damage to hearing — damage that cannot be repaired through surgical procedure or the use of hearing aids. Researchers who studied one freshman class at the University of Tennessee found that 35 percent of the class had deteriorating hearing levels usually associated with senior citizens in an industrialized society. Yet senior citizens who reside in less industrialized societies do not demonstrate deteriorating hearing levels with advancing years.

As for other health problems, the evidence that is in so far indicates that exposure to noise can cause stress and aggravate a number of heart problems. Noise, like other forms of stress, seems to cause physiological changes that are controlled by the involuntary nervous system. These include changes in heart rate, hormone secretions, blood pressure, blood cholesterol levels, and in the rate of acid secretion in the stomach. Often a person is unaware that these changes are occurring until the stress-related ailments occur — such things as ulcers, indigestion, heartburn, gastrointestinal malfunctions, heart disease, and mental illness.

Scientists suspect that noise-induced stress leads to yet other health problems. A five-year study of two manufacturing firms found evidence that workers in noisy plant areas showed greater numbers of health problems such as respiratory ailments.

Studies also show that the effects of noise pollution may begin earlier in our lives than we may realize, even before birth. Doctors have found that a fetus responds to sound with a kicking movement. The unborn child is also susceptible to stress-induced harm, and indirect evidence links noise stress with low birth weights. A Japanese study of more than 1,000 births indicated a high proportion of low-birthweight babies in high-noise areas.

A DEAF EAR?

Implicit in this mixed bag of evidence is that the noise around us is harmful. Yet, even with these conclusions, it is difficult to be fully and legally protected from it.

In 1972, Congress passed the Noise Control Act, which established a national policy "to promote an environment for all Americans free from noise that jeopardizes their public health and welfare."

Congress gave the Environmental Protection Agency (EPA) the responsibility to set the standards of noise levels in the workplace. Working with the Occupational Health and Safety Administration (OSHA), guidelines and regulations were established. The maximum exposure legally allowed for workers without hearing protection for an eight-hour day is 90 dB. If working conditions are louder, the worker has to work fewer hours. (For every five decibel increase, the worker must halve the time spent in that environment.

So, for example, at 100 dB, a worker can only work for two hours.)

But, according to William Clark, a specialist in physiological acoustics at the Central Institute for the Deaf, Washington University, St. Louis, the 90 dB limit is not enough. "The real truth of the matter," he says, "is that the 90 dB exposure is not a safe exposure with regard to functional damage to the ear. The experiments we do show that 85 dB is better, but even that is not safe."

Economic and political pressures, however, have prevented enactment of a law to lower the maximum decibel level in the workplace from 90 to 85. As more evidence about adverse health effects of noise accumulate, it may be easier to push through such a law on the Federal level.

On the local level, some businesses and industries require earplugs and other hearing protection devices for their workers. Others muffle the loud machinery. Some communities have established ordinances that set decibel limits for various community noise sources and prohibit some noisy activity while limiting hours of others. Many communities in the Washington, DC area, for instance, have established these codes and levy strict fines on the violators.

In the Chicago area, people living near the O'Hare International Airport, the nation's busiest airport, complained for years about the noisy air traffic. As a result, some planes, when it is not a safety hazard for the passengers, muffle their engines and make other adjustments. Other airports around the country sometimes reroute or reschedule their flights in consideration of the nearby neighbors.

LEND AN EAR

What can you do to protect yourself from all the noise in the world?

- Wear hearing protection if you expect to be exposed to sounds higher than 85 decibels for a long period of time.
- Be aware of the noise level of equipment used in the home. The accompanying chart and sidebar should help.
- Ask yourself if you really need to have the stereo, TV, or headset turned up as high as you have it.

As for cheering for your favorite team in the playoffs, probably one noisy game won't make that much difference in the overall state of your hearing. But, maybe it would be a good idea to root for a team that doesn't get to the playoffs every year!

"Noise Pollution," Current Health 2, October, 1984, pp 11-13. Curriculum Innovations, Inc. Reprinted with permission. Further reproduction prohibited.

NOISE AT HOME

Noise Sound	Sound Level for Operator (in dB)
Refrigerator	40
Floor Fan	38 to 70
Clothes Dryer	55
Washing Machine	47 to 78
Dishwasher	54 to 85
Hair Dryer	59 to 80
Vacuum Cleaner	62 to 85
Sewing Machine	64 to 74
Electric Shaver	75
Food Disposal (Grinder)	67 to 93
Electric Lawn Edger	81
Home Shop Tools	85
Gasoline Power Mower	87 to 92
Gasoline Riding Mower	90 to 95
Chain Saw	100

Chart: Courtesy U.S. EPA

SOUND LEVELS AND HUMAN RESPONSE

Common Sounds	Noise Level (dB)	Effect
Carrier deck jet operation Air-raid siren	140	Painfully loud
Jet takeoff (200 feet) Thunderclap Discotheque Auto horn (3 feet) Stereo (full blast)	120	Maximum vocal effort
Heavy truck (50 feet) City traffic	90	Very annoying Hearing damage (8 hours)
Alarm clock (2 feet) Hair dryer	80	Annoying
Noisy restaurant Freeway traffic Man's voice (3 feet)	70	Telephone use difficult
Air-conditioning unit (20 feet)	60	Intrusive
Light auto traffic (100 feet)	50	Quiet
Library Soft whisper (15 feet)	30	Very quiet

Chart: Courtesy U.S. EPA

C-4. HOW COLOR AFFECTS YOUR MOODS AND HEALTH

The 16-year-old boy, high on the drug PCP, or "angel dust," struggles wildly as the four policemen he attacked minutes earlier escort him into juvenile hall in San Bernadino, Calif. Inside he asks to use a telephone, but moments later, in a berserk frenzy, he is smashing the telephone into the head of a staff worker.

Finally restrained, the boy is taken to an 8-by-4-foot concrete room — one strikingly different from the typical jail cell. Its walls are a bright, eye-shocking pink. At first the drugged youngster pounds the walls violently, but six minutes later he is sitting calmly. Within 15 minutes he is lying on the floor, almost asleep.

Colors possess magical powers, many ancient peoples believed. Even today we commonly assume a link between colors and our mind. The optimist, we say, views the world "through rose-colored glasses." When sad, a person is in a "blue mood." And now, scientists are discovering that certain colors indeed have a profound influence on our bodies, moods, thoughts, and behavior.

MIND'S EYE

What is color? A few years ago a scientist might quickly have answered that color is energy — electromagnetic-light energy rippling through space in waves of certain lengths. By this definition, the light we call red at the bottom of the rainbow spectrum ripples at a wavelength — a distance between the crests of its waves — of about 617 nanometers, roughly 205 billionths of a foot. Near the top of the spectrum, blue light ripples at a wavelength of 470 nanometers. Midway between, green light ripples at 532 nanometers. When these three primary spectrum colors combine in equal amounts, the result is what we perceive as white light. When red and green light blend, the result is yellow. Blue and red added together produce magenta; blue and green combine to make cyan. Our eyes, these scientists said, simply have the ability to distinguish and identify these wavelengths of light emitted or reflected by things around us.

But this view of color is too simple according to some research scientists. Color, they say, exists not only in the eye, but also in the mind of the beholder.

As a young experimenter, Edwin H. Land, the inventor of Polaroid instant photography and today chairman of the board of the Polaroid Corporation, became fascinated with color. How is it, he wondered, that a photograph taken under the reddish glow of a tungsten lamp will show objects colored by its reddish hue — yet when we view the same scene with our eyes, oranges remain orange, bananas yellow, leaves green, blue tableware blue? Land recognized that our eyes and brain have a remarkable ability to paint the world in its 'true' colors inside our heads, even when the wavelengths of light coloring that world suddenly change or are partly missing.

INNER VISION

How then do we perceive these colors? Scientists have yet to answer, but recent discoveries have given astonishing insights into the complexity of eyesight.

Light falling on the eye is focused by its lens onto two general types of receptors. Every eye contains 120 million rods, each of which carries inside it 130 million molecules of a chemical pigment called rhodopsin that changes electrically when light hits it. The primary purpose of the rods in our eyes is night vision, although scientists are now discovering that they also help our brain monitor the brightness and other factors that are key to how the brain colors our world.

Every eye also holds 6 million receptors called cones. They come in at least three varieties, each of which contains a pigment that differs in sensitivity to light. One type of cone has its peak reaction to yellow light, a second responds optimally to green, and a third to blue. But each cone reacts to a spectrum of vibrations, and thus the three types overlap in their range of colors. In each cone, therefore, any visible wavelength of light will evoke an electrical signal, a bit of information that the brain uses in puzzling out that instant's mosaic of what the eye sees.

The brain has been called an enchanted loom. Somehow it is able to take the shifting electrical signals from 252 million rods and cones in your eyes and, moment by moment, weave those tiny snippets of information into a tapestry portrait of what is before you.

To work this awesome magic, an estimated one-third of the gray matter of your brain is involved in processing visual information. But even before signals from the rods and cones reach the brain, they pass through a

switchboard of ganglion cells. These cells sort, compare, and encode the information.

When the signals reach the brain, they are taken over by an awesome visual bureaucracy of specialized cells. Cells in specific areas of the brain, it seems, process the signals associated with individual colors. Groups of cells set thresholds that define the brightness or darkness of a color. And some, amazingly, respond to color only when it is framed by a particular shape or in a certain pattern.

Researchers had long known that by staring at a red square, the mind can be prompted to generate a brief after-image in green, called its opponent color because many visual cells switch between signaling red or green (as others switch between blue and yellow, which is why such colors seem to flicker where they are placed next to each other). But in 1965 psychologist Celeste McCollough, at Oberlin College in Ohio, discovered that when a person stares at certain grid patterns with alternating vertical red and black stripes juxtaposed to horizontal patterns of green and black stripes, the opponent-color after-images can last for hours — or even weeks. This has aroused intense interest among some scientists. The mind, it seems, relies on edges, lines and borders to define what is seen just as much as it needs information about frequency of light waves.

BANK BLUE

Naturalists have known of this mysterious alchemy of color and pattern for decades. Brightly colored tropical fish are acutely sensitive to how color is configured on one another's bodies. Animals know instinctively how to display the patterns of color on their bodies as signal flags communicating subtle messages to other creatures.

Other living things do not think about or debate such messages of color and shape. The responses are automatic. Scientists have found that certain young fish seek safety by moving toward patterns of color and shape that mimic their parents. As thinking human beings, we prefer to consider ourselves above such influences. We cannot be prompted to do things by a mere flag, an exact blend of color and shape that acts as a key unlocking automatic impulses in our minds and bodies. Or can we? Could a male be prompted to courtship, for example, by noticing a rush of blood reddening a young woman's lips — a clear sign of rising blood pressure and aroused emotions? Would our ancient ancestors have noticed such subtle things? Perhaps the widespread use of red lipstick by women since the time of the pharaohs in Egypt has served to trigger just such an inborn impulse in the male eye.

Businesses have paid millions to psychologists for research to discover which colors and patterns will prompt people to buy their products. It is no accident that so many boxes on the shelves of your supermarket are colored with hues of red and yellow. The consumer passing down a market aisle will lay eyes on a package for just a short time, and in that time the package must arrest the eye and convey a positive image. Red and yellow do this, perhaps because they come from a part of the visible spectrum associated with sunlight and fire. These colors also make the package appear a bit bigger than it really is.

According to Swiss psychologist Max Luscher, lecturer at the University for Artistic and Industrial Design in Linz, Austria, and an expert widely consulted by manufacturers and advertisers, colors arouse specific feelings in people. Blue conveys peace and contentment, but those who favor dark blue are motivated by a need for security. Blue is widely used in the symbols of banks and automobile manufacturers. Yellow, says Luscher, is associated by most people with modernity, achievement, and the future. Red conjures up power, an urge to win, vitality; it is the color chosen by many cigarette and soft-drink makers to wrap their products. Green and red together stir feelings of strength, reliability and incorruptibility. Greenish-blue invokes a sense of security and self-esteem, according to Luscher. Children, he finds, prefer bright primary colors that prompt immediate emotions. Adults prefer subdued colors.

TRIBUTE TO THE BRAIN

Psychologists recently have recognized that colors can elicit emotions because of cultural associations. The sight of our nation's flag can stir feelings of patriotism and affection. But can colors and patterns also induce direct biological changes in people?

The answer appears to be yes, as evidenced by the drugged boy in the pink cell. Indeed, in numerous tests where violent prisoners were put in pink cells, the results proved that a particular pink color has the power to tranquilize, to replace aggressive impulses with passivity. One researcher says the pink rooms seem to induce long-term changes in those exposed to them. Another has done experiments showing that even a brief dose of the pink can cause a measurable weakening of the body's muscles that lasts for about 30 minutes. But he has also found an antidote: a few seconds' exposure to blue can restore the power drained by exposure to pink. In addition, it has been found that the pink detention cells have the same tranquilizing effects on color-blind prisoners who are unable to "see" pink.

In laboratory experiments scientists have raised generations of mice under colored lights. Different colors caused the organs of their bodies to grow at different rates. A rainbow also caused a spectrum of activity: mice living under green light were least active; those under red light were most active.

Light and color cause startling changes in many living things. A single flash of red light can alter the biological clocks of algae, and prolonged exposure to such light can arouse the mating impulse in birds and raise the hormone levels in mice, for example.

Scientists have found that people, likewise, can be profoundly influenced by exposure to colors. Not surprisingly, exposure to what interior decorators call the 'hot' color red makes people perceive their environment as warmer than measured by a thermometer. Soviet studies have shown that people working under red illumination tend to react more quickly than others, but their efficiency in performing tasks is greatly reduced. Both Soviet and Japanese scientists agree that red light can alter the normal electrical patterns of the brain. Even a brief exposure to red, American scientists discovered, causes an immediate change in the way electricity travels through human skin.

Do such findings matter to people not living under red light? Perhaps not, but the ordinary incandescent light bulbs under which millions of people live and work do not put out the same color intensities of light found in natural sunshine. No, that screw-in incandescent bulb that has enlightened our world since Thomas Edison developed it 103 years ago gives off predominantly red light. The fact that you perceive a world of correct colors both under its reddish glow and under the green, yellow and violet rays of cool, white, fluorescent bulbs is a tribute to your brain's amazing ability to color your thinking as it colors your world.

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C-5. HEAT: AN ATOMIC DANCE

WHAT IS HEAT?

For centuries, it was believed to be a weightless substance, called caloric, contained to some degree in all matter. According to this view, the caloric present in wood was released by burning.

This theory began to give way in 1798 when an American scientist known as Count Rumford proposed that "heat could not be a material substance, but must be something of the nature of motion." He was right, but a clearer idea of the nature of heat had to wait until scientists understood the atomic nature of matter. Now we know that what we perceive as heat is actually electrons, atoms and molecules in motion — vibrating, moving in all directions and bumping into one another. And temperature is a measure of how briskly they are moving.

When a pot of water is heated on a stove, the rapidly moving molecules of the gases in the flame crash into the pot, as does infrared radiation emitted by the moving molecules. This causes free electrons in the metal to collide with their neighbors, accelerating them toward the water. Eventually this motion is imparted to the water molecules at the bottom of the pot. These rise and colder ones sink to take their place — a process known as convection. When the water molecules are moving violently enough, bonds between them begin to break, allowing some of them to escape as steam.

In general, metals have many free electrons, which conduct heat quickly. Water and air have no free electrons, and their molecules aren't so easily accelerated. Thus, they don't conduct heat as well and are good insulators.

The worst conductor of all is empty space. A vacuum between the double glass walls of a thermos bottle slows the movement of heat out of your warm coffee or into your cold milk. But since heat can still be conducted through the vacuum by infrared radiation, the walls of the thermos are coated with a silvery substance to block these rays.

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